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Supplement

ANL-7499  
Supplement

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# Argonne National Laboratory

## INELASTIC RESPONSE OF PRIMARY REACTOR CONTAINMENT TO HIGH-ENERGY EXCURSIONS

by

Joseph Gvildys and Stanley H. Fistedis

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Reactor Analysis and Safety Division

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## TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT . . . . .	5
I. INTRODUCTION . . . . .	5
II. STABILITY OF THE DIFFERENTIAL EQUATIONS . . . . .	5
III. EQUATION OF STATE FOR A GROUP OF MIXED MATERIALS . . . . .	7
A. Mixtures Composed of Liquids and Solids . . . . .	8
B. Mixtures Composed of Gases, Liquids, and Solids . . . . .	9
IV. DESCRIPTION OF COMPUTER PROGRAM . . . . .	12
V. COMPARISON WITH EXPERIMENTAL RESULTS . . . . .	13
APPENDIX - FORTRAN Program Listing . . . . .	18
ACKNOWLEDGMENT . . . . .	50
REFERENCES . . . . .	51

## LIST OF FIGURES

(Continued from page 4 of ANL-7499)

<u>No.</u>	<u>Title</u>	<u>Page</u>
9.	Elastic-Plastic Behavior of Porous Material before Complete Compaction . . . . .	11
10.	Cross Section of Model Core and Breeder Structure for UKAEA Experiments [from N. J. M. Rees (UKAEA), <i>A Model Investigation of Explosion Containment in Single Tank Fast Reactors</i> , pp. 692-719 in ANL-7120, Proc. of the Conf. on Safety, Fuels, and Core Design in Large Fast Power Reactors, Oct. 11-14, 1965] . . . . .	14
11.	Cross Section of Model Reactor Tank, Showing Positions of Pressure Gauges and the Center of Charge [from N. J. M. Rees (UKAEA), <i>A Model Investigation of Explosion Containment in Single Tank Fast Reactors</i> , pp. 692-719 in ANL-7120, Proc. of the Conf. on Safety, Fuels, and Core Design in Large Fast Power Reactors, Oct. 11-14, 1965] . . . . .	15
12.	Configuration of Confined Charge at Initial Time Compared with Distortion at Time of Peak Pressure at Position of Gauge 3 . . . . .	16
13.	The Computed Pressure Trace at the Position of Gauge 3 for the Confined Charge . . . . .	16

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ABSTRACT

The analytical part of the inelastic response of primary containment to high-energy excursions was presented in the first part of this report. This supplement integrates the effort in this area. It adds primarily the computer program and some other analytical considerations, such as a numerical stability criterion, equations of state of mixed materials, and some comparison of the code with experimental results.

I. INTRODUCTION

The mathematical formulations, finite-difference equations, and numerical techniques for calculating the inelastic response of primary containment to a high-energy axisymmetric excursion have been described in detail in the first part of ANL-7499. The main purpose of this second part (ANL-7499 Supplement) is the presentation of the corresponding computer program and the addition of developments making the overall report self-contained. Thus, this part gives a numerical stability criterion, new analytical considerations, and a comparison with experimental results, all of which had not been included in the first part of the report.

Since the material given in this part is a continuation of the preceding work, the same sequence of equations and figures is maintained. Whenever possible, the same nomenclature is used in this part of the report to preserve continuity. However, all symbols are identified wherever they first appear in the text.

II. STABILITY OF THE DIFFERENTIAL EQUATIONS

The stability equations (Eqs. 74 - 76) are used to determine the length of the time step  $\Delta t$  so that a small disturbance can extend no

further than the local zone spacing during  $\Delta t$ . In the meantime, a lower limit is chosen to avoid excessive computations resulting from  $\Delta t$  being unnecessarily small. Equation 74 is the simplified form of the White stability equation<sup>6</sup> derived for the pseudoviscosity method. After careful comparison of the results of the computer output with an existing known solution, it was found that Eq. 74 was inadequate. The restriction imposed by the first term on the right side of Eq. 74 was too severe for certain reactor materials. It was, therefore, decided to use the White stability criterion in its originally derived form, that is,

$$W = \left[ \frac{c^2 (\Delta t)^2}{A} + 4a^2 \left| \frac{\Delta V}{V} \right| \right]^{1/2} < 1,$$

where  $W$  is White stability number,  $c$  is the speed of sound, and  $\Delta V$  is the change of specific volume. For enhanced computational stability, the range of  $W$  is limited to values<sup>7</sup> between 0.45 and 0.2245.

For each zone the White stability number is obtained from

$$\left( \frac{W}{1.2} \right)^2 = \frac{c^2}{A} \left( \frac{\Delta t}{1.2} \right)^2 + 4 \left| \frac{\Delta V}{V} \right|, \quad (137)$$

where  $a$  is taken as 1.2, and the time interval  $\Delta t$  is selected so that the maximum of the stability numbers for all zones satisfies

$$0.035 < \left( \frac{W}{1.2} \right)_{\max}^2 < 0.14. \quad (138)$$

The speed of sound is given by

$$c^2 = -V^2 \left( \frac{\partial p}{\partial V} \right)_S. \quad (139)$$

The adiabatic equation of state for gaseous materials is taken as

$$pV^\gamma = \text{constant}, \quad (140)$$

where  $\gamma$  is the isentropic exponent. Thus,

$$c = (\gamma p V)^{1/2}. \quad (141)$$

For solids and liquids, the adiabatic equation of state is assumed to have the form

$$p = p_B \left[ \left( \frac{V_0}{V} \right)^\eta - 1 \right]. \quad (142)$$

Upon applying Eq. 139, the speed of sound becomes

$$c = [\eta V(p + p_B)]^{1/2}. \quad (143)$$

In the above expression, the constants  $p_B$  and  $\eta$  are related by

$$c_0^2 = V_0 p_B^\eta, \quad (144)$$

where  $c_0$  is the speed of sound indicated in Fig. 9.

Substitution of Eqs. 141 and 143 into Eq. 137 gives White's stability criterion as

$$\left( \frac{W}{1.2} \right)^2 = \frac{\eta V(p + p_B)}{A} \left( \frac{\Delta t}{1.2} \right)^2 + 4 \left| \frac{\Delta V}{V} \right|. \quad (145)$$

The above applies both to condensed materials and gases. The value of  $p_B$  is taken as zero for gases.

### III. EQUATION OF STATE FOR A GROUP OF MIXED MATERIALS

As stated in the first part of this report, solution of the basic conservation equations of mass, momentum, and energy requires an equation of state of the form

$$p = p_H + \frac{\gamma}{V} (E - E_H), \quad (54)$$

where  $p_H$  and  $E_H$  are the pressure and specific internal energy along the Hugoniot centered at  $p_0$ ,  $V_0$ ;  $V$  is the specific volume; and  $\gamma$  is the Mie-Grüneisen coefficient (see Sect. III.A of ANL-7499). Thus, analysis of the inelastic response of a primary reactor-containment structure to high-energy excursions requires knowledge of the equation of state of the reactor materials.

In the numerical solution, meshes represent the primary system media. No problem exists in representing single materials such as steel or sodium. There is sufficient experimental Hugoniot data for common materials. M. van Thiel<sup>8</sup> provides substantial experimental data. The results of these experiments, although performed under different environmental conditions than in reactors, can be made applicable for containment calculations.

A problem is created when media like the core blanket and plenum are divided into meshes. Individual meshes could involve more than one material. Extremely fine meshes are required to confine one material to each mesh zone. Thus, a Hugoniot curve is needed to represent the pressure-volume relations for material mixtures. Currently experimental data are not available for such mixtures. To remedy this situation it is necessary to develop a method to provide a Hugoniot curve for the mixture, from currently available Hugoniot data for individual materials.

The approach employed in this analysis is similar to that used by Goranson *et al.*<sup>9</sup> in describing the dynamic compressibility of metals. The two basic assumptions are: (1) all components of the mixture within a mesh zone experience the same temperature and pressure; and (2) all components under pressure maintain their integrity.

#### A. Mixtures Composed of Liquids and Solids

The Mie-Grüneisen type of equation of state applies to both solids and liquids and can be used for easy construction of an equation of state for a mixture of solids and liquids.

The initial volume for a hypothetical mixture with  $n$  components is

$$\Psi_0 = \sum_{i=1}^n \Psi_{0i}, \quad (146)$$

where  $\Psi_{0i}$  represents the initial volume of component  $i$ . For a specific value of  $p_H$ , the total volume of the mixture is

$$\Psi = \sum_{i=1}^n \psi_i = \sum_{i=1}^n \frac{\psi_i}{\psi_{0i}} \psi_{0i} = \sum_{i=1}^n \left( \frac{\psi_i}{\psi_{0i}} \right)_{p_H} \psi_{0i}, \quad (147)$$

where  $\psi_i$  is the volume,  $\psi_i$  the specific volume, and  $(\psi_i/\psi_{0i})_{p_H}$  is the relative specific volume of the component  $i$ . The value of  $\psi_i/\psi_{0i}$  is obtained from the Hugoniot curve for the individual element.

The relative compression of the mixture is obtained from Eqs. 146 and 147:

$$\frac{\Psi}{\Psi_0} = \sum_{i=1}^n \left( \frac{\psi_i}{\psi_{0i}} \right)_{p_H} \frac{\psi_{0i}}{\psi_0}, \quad (148)$$

where  $\Psi/\Psi_0$  is the relative volume of the mixture at pressure  $p_H$ , and  $\psi_{0i}/\psi_0$  is the volume fraction of component  $i$ . A plot of  $p_H$  versus  $(\Psi/\Psi_0)_{p_H}$  as determined by Eq. 148 yields the Hugoniot curve of the mixture of  $n$  components.

#### B. Mixtures Composed of Gases, Liquids, and Solids

For mixtures composed of gases, liquids, and solids, the phenomenon of shock compression is more complex than in mixtures containing only solids and liquids. A satisfactory approximation treats the gases as voids and the remainder of the mixture as porous material. As the shock compression starts, the work of the external pressure is expended in squeezing the voids and in packing the material, thus reducing it to a standard volume (standard volume refers to the condition without internal voids). The energy expended in compressing the gases is neglected. This approximation results in small errors.

##### 1. Hydrodynamic Crushing

In the hydrodynamic crushing, the mixture is assumed to behave hydrodynamically, i.e., with zero shear stresses. The material in each mesh is allowed to be loaded up to its yield stress to overcome the initial

rigidity, and then to compact at constant stresses until the voids are completely closed.

Let  $V_0$  be the standard specific volume of the mixture and  $V_{00}$  the specific volume of the porous mixture. Then a  $p_H(v, V_0)$  curve can be constructed for the continuous mixture, containing no internal voids, using the approach outlined in Sect. III.A of the first part. If the Mie-Grüneisen coefficient  $\gamma$  is assumed to be a function of volume, the Hugoniot curve of the porous mixture can be approximated by

$$p_H(v, V_{00}) = p_H(v, V_0) + \frac{\gamma}{V} [E(v, V_{00}) - E(v, V_0)], \quad (149)$$

where

$$\left. \begin{aligned} E(v, V_{00}) &= \frac{1}{2} p_H(v, V_{00})(V_{00} - v) \\ E(v, V_0) &= \frac{1}{2} p_H(v, V_0)(V_0 - v) \end{aligned} \right\} \quad (150)$$

and

Equation 150 gives the internal energy of the porous and continuous mixture, respectively.

Substitution of Eq. 150 into Eq. 149 and simplification gives

$$p_H(v, V_{00}) = \left[ 1 + \frac{\frac{V_0}{V_{00}}}{\frac{V_0}{V_{00}} K - 1} \right] p_H(v, V_0), \quad (151)$$

where

$$K = \frac{2}{\gamma} + 1.$$

Thus, the Hugoniot plot of a mixture is represented by a straight line on the axis  $V$  from  $V_{00}$  to  $V_0$  and then a curve from  $V_0$  to  $V$ , according to Eq. 151.

## 2. Elastic-Plastic Crushing

In elastic-plastic crushing, the mixture is considered to be elastic-plastic, i.e., shearing and energy dissipation by plastic flow is included in the crushing of voids. For ductile porous materials, the constitutive equation for the dynamic compaction has been discussed by Herrmann.<sup>10</sup> The differential equation for the elastic compression or recompression curves shown in Fig. 9 is given by

$$\frac{d\left(\frac{V}{V_0}\right)}{dp} = \frac{V}{V_0 B_0} \left[ 1 - \frac{\frac{V}{V_0}}{h^2\left(\frac{V}{V_0}\right)} \right], \quad (152)$$

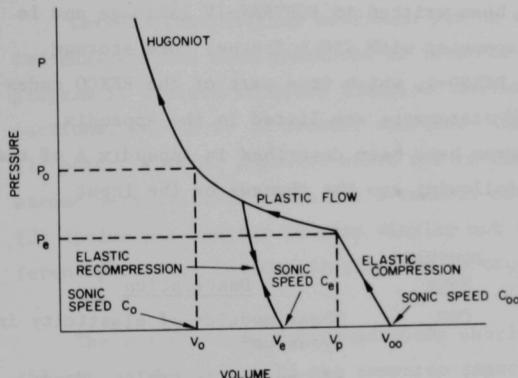


Fig. 9.  
Elastic-Plastic Behavior of  
Porous Material before  
Complete Compaction  
ANL Neg. No. 900-807.

where  $V_0$  and  $B_0 (= c_0^2/V_0)$  are the specific volume and bulk modulus of the solid material in the undeformed state, and  $c_0$  is the speed of sound in the solid material. The function  $h\left(\frac{V}{V_0}\right)$  is assumed to have a linear relation:

$$h\left(\frac{V}{V_0}\right) = a \frac{V}{V_0} + b, \quad (153)$$

where

$$\left. \begin{aligned} a &= \left( \frac{c_{00}}{c_0} - 1 \right) / \left( \frac{V_e}{V_0} - 1 \right) \\ b &= 1 - a \end{aligned} \right\}, \quad (154)$$

in which  $c_0$  is the speed of sound in the porous material. The plastic curve is represented by the following quadratic equation:

$$\frac{V - V_0}{V_p - V_0} = \left( \frac{P_0 - P}{P_0 - P_e} \right)^2, \quad (155)$$

The quantities  $P_0$ ,  $P_e$ ,  $V_e$ , and  $V_p$  are defined in Fig. 9. Thus, if sonic speeds  $c_0$  and  $c_{00}$  and the elastic limits are known, one can construct an elastic and plastic compressive curve from  $V_{00}$  to  $V_0$ , when the mixture is fully compacted. After full compaction, one should use the Hugoniot for the hydrodynamic case as outlined above.

#### IV. DESCRIPTION OF COMPUTER PROGRAM

The computer program has been written in FORTRAN-IV language and is conducted with an IBM-360-75 computer with 750 k (bytes) core storage. The computer code is known as REXCO-I, which is a part of the REXCO codes developed at ANL. The FORTRAN statements are listed in the Appendix. Input instructions to the program have been described in Appendix A of the first part of ANL-7499. The following are the changes of the input instructions:

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>FORTRAN Name</u>	<u>Description</u>
11	37-45		CNU <sub>k</sub>	Shear modulus of elasticity in dynes/cm <sup>2</sup>
16		(8F9.0)		KZ <sub>I</sub> versus Z <sub>I</sub> table. Used only when KPPX > 0 on card of type 15.
1-9			CX <sub>1</sub>	KZ <sub>1</sub>
10-18			CXD <sub>1</sub>	Z <sub>1</sub> } KZ <sub>I</sub> is the spring force, in dynes, for the dis-
19-27			CX <sub>2</sub>	Z <sub>2</sub> } placement Z <sub>I</sub> , in cm.
28-36			CXD <sub>2</sub>	

Use as many cards of type 16 as required.

Note: The KZ<sub>I</sub> versus Z<sub>I</sub> values are entered in pairs in decreasing order of Z<sub>I</sub>, starting with Z<sub>1</sub> (largest displacement), Z<sub>2</sub>, ..., to Z<sub>KPPX</sub>.

<u>Card Type</u>	<u>Columns</u>	<u>Format</u>	<u>FORTRAN Name</u>	<u>Description</u>
17		(8F9.0)		$C\dot{z}_I$ versus $\dot{z}_I$ table. Used only when KPPC > 0 on card of type 15.
1-9			$CV_1$	$C\dot{z}_1$
10-18			$CVD_1$	$\dot{z}_1$
19-27			$CV_2$	$C\dot{z}_2$
28-36			$CVD_2$	$\dot{z}_2$

Use as many cards of type 17 as required.

Note: The  $C\dot{z}_I$  versus  $\dot{z}_I$  values are entered in pairs in decreasing order of  $\dot{z}_I$ , starting with  $\dot{z}_1$  (largest velocity),  $\dot{z}_2$ , ..., to  $\dot{z}_{KPPC}$ .

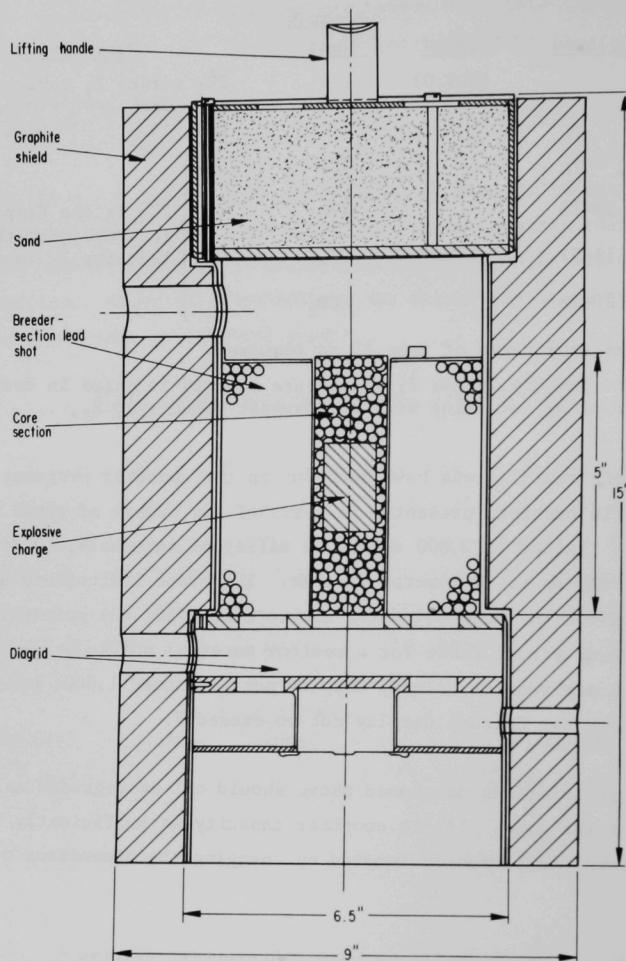
Certain restrictions have been put on the computer program, although the analysis has been presented in terms of any number of zones. The program is limited to 3,000 zones, 20 different materials, 20 different sections, and up to 10 reactor vessels. The other limitations are:

- (1) points for the Hugoniot curve not to exceed 50; (2) points for a stress versus strain table for a reactor material not to exceed 50;
- (3) cycles per run for Calcomp display not to exceed 1,000; and (4) different plots for Calcomp display not to exceed 7.

The restrictions mentioned above should not be regarded as limiting the use of the code. If the computer capacity is sufficiently large, the restrictions can be easily removed by changing the dimensions of the program.

## V. COMPARISON WITH EXPERIMENTAL RESULTS

The accuracy of the numerical method has been evaluated by Ash and Julke<sup>11</sup> by comparison with experimental results. The experimental test selected for comparison was performed by the UKAEA. It consisted of an enclosed 2-oz charge of RDX/TNT 60/40 and a rigid containment tank (shown in Fig. 10). The cross section of the tank, positions of the pressure gauges, and the center of the charge are shown in Fig. 11. The idea of using an enclosed charge was to delay the time of arrival of the pressure



*Fig. 10. Cross Section of Model Core and Breeder Structure for UKAEA Experiments [from N. J. M. Rees (UKAEA), A Model Investigation of Explosion Containment in Single Tank Fast Reactors, pp. 692-719 in ANL-7120, Proc. of the Conf. on Safety, Fuels, and Core Design in Large Fast Power Reactors, Oct. 11-14, 1965]. ANL Neg. No. 900-673.*

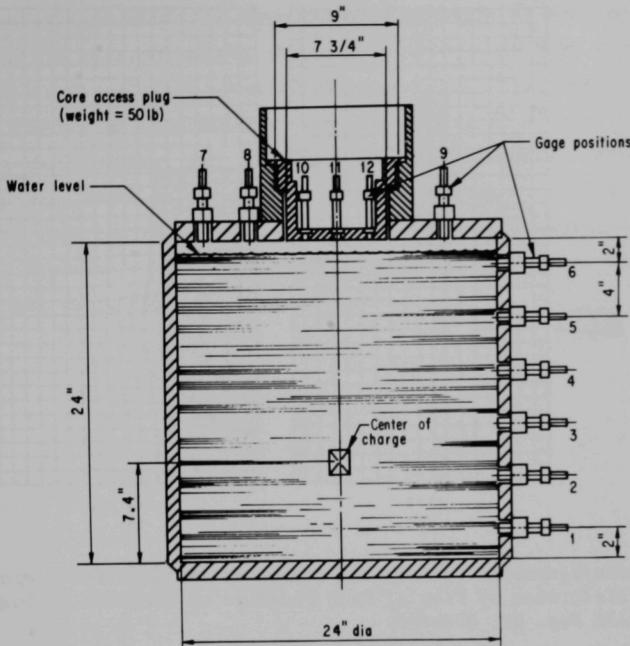
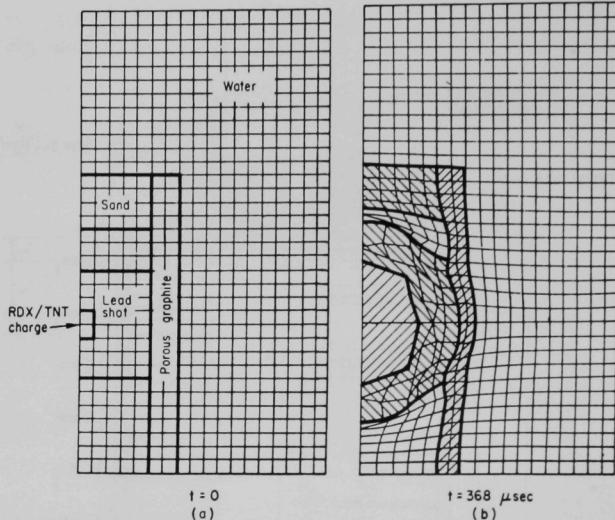


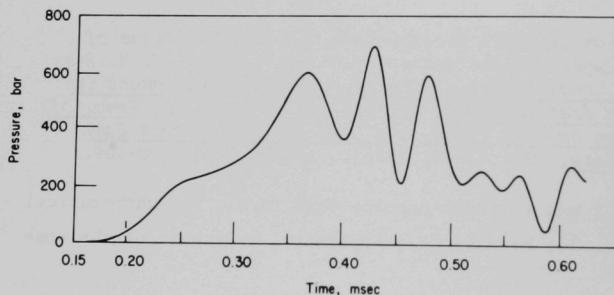
Fig. 11. Cross Section of Model Reactor Tank, Showing Positions of Pressure Gauges and the Center of Charge [from N. J. M. Rees (UKAEA), A Model Investigation of Explosion Containment in Single Tank Fast Reactors, pp. 692-719 in ANL-7120, Proc. of the Conf. on Safety, Fuels, and Core Design in Large Fast Power Reactors, Oct. 11-14, 1965]. ANL Neg. No. 900-654.

wave reaching the wall and to smear out the wave form. The mathematical model is shown in Fig. 12; because of axisymmetry, only half of the configuration is shown.

The computed pressure history at the position of gauge 3 is shown in Fig. 13. The peak pressure was 0.60 kbar, which was not as low as the measured peak value of 0.24 kbar.<sup>12</sup> The deformation of the grid at the time of peak pressure at the position of gauge 3 is shown in Fig. 12. Subsequent studies reveal that the source of error was in the equation of state of the materials. Particularly unreliable is the description of the lead shot. For instance, if the lead shot was assumed to be water saturated, the energy absorption of the confining structure became



*Fig. 12. Configuration of Confined Charge at Initial Time Compared with Distortion of Time of Peak Pressure at Position of Gauge 3. ANL Neg. No. 900-806.*



*Fig. 13. The Computed Pressure Trace at the Position of Gauge 3 for the Confined Charge. ANL Neg. No. 900-678.*

unrealistically low. If the lead shot was treated as a truly porous material and was allowed to absorb the energy in the crushing of the voids, the peak pressure was attenuated to one-half of the peak for the water-filled voids. Since the performance of a similar code, REXCO-H,<sup>13</sup> has been well-established by comparison with experimental results, it is fairly clear that the discrepancy is due largely to the inaccurate description of the lead shot rather than to deficiencies in the basic REXCO-I code. In one of the trial computations, all materials were

treated hydrodynamically; the computer peak pressure at the position of gauge 3 was 1.1 kbar, which was about twice as much as that calculated based upon elastic-plastic behavior of materials. This leads to the important conclusion that shear stress and plastic-flow effects cannot be ignored in the analysis, and that development of inelastic codes parallel to hydrodynamic codes is necessary. As a final remark, to obtain a better correlation with the experiments, an improvement on the equations of state is needed, especially when the material to be treated is not homogeneous and isotropic as in the case of lead shot.

## APPENDIX

FORTRAN Program Listing

```

C MAIN PROGRAM 0001
C J.GVILDOYS-2/27/68 0002
C TWO-DIMENSIONAL REACTOR ACCIDENT ANALYSIS 0003
C IMPLICIT REAL*8(A-H,O-Z) 0004
COMMON /D/ R(3000),Z(3000),RDOT(3000),ZDUT(3000),E(3000),P(3000), 0005
1RH0(3000),VP(3000),SC(3000),SDR(3000),SDZ(3000),SDT(3000),SRL(3000) 0006
2),MZERO(3000),RD(3000),ZD(3000),SSR(3000),SSZ(3000),SST(3000), 0007
3SSRZ(3000),STR(3000),STZ(3000),KTX(3000),KTY(3000) 0008
DIMENSION TITLE(20) 0009
DIMENSION PP(20,50),VV(20,50),PO(20),EU(20),GO(20),CO(20), 0010
1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20) 0011
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20) 0012
DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20) 0013
DIMENSION CIJ(50),CXIJ(1000) 0014
CCMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL, 0015
1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IMD,JDM,NPP,NCL 0016
2,KXP(20),KYP(20),KXYP(1000) 0017
COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2 0018
COMMON K1I(50),K12(50),KJ1(50)*KJ2(50)*KXI(1000),KXJ(1000) 0019
CCMMON I11(10),I12(10),I21(10),I22(10),J11(10),J12(10),J21(10), 0020
1J22(10),I1X,I2X,J1X,J2X,KK(120) 0021
CCMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,EU,GO,CO,AA,BB, 0022
1 CC,VN,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD+PMASS 0023
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYD,CNU,CIJ,CXIJ 0024
3,PLGF(1000),TME(1000),PRS16,1000) 0025
REAL*4 TME,PLGF,PRS,TIN 0026
REAL*4 TITLE 0027
REAL*8 MZERC 0028
INTEGER*2 KTX,KTY 0029
C FORMATS FOR MAIN PROGRAM 0030
500 FFORMAT(18A4) 0031
502 FORMAT(5I6,3F12.0) 0032
503 FFORMAT(6F12.0) 0033
504 FFORMAT(12I6) 0034
505 FFORMAT(3I6,2F12.0) 0035
506 FORMAT(1H1,20X,18A4) 0036
508 FORMAT(1HC,' NO OF R ZONES =',I3,' NO OF Z ZONES =',I3, 0037
1' INITIAL D-TIME =',E15.7) 0038
510 FORMAT(1HC,' LIMITING CONSTANTS'/1H0,' MAX CYCLES =',I5, 0039
1' MAX TIME =',E15.7,' MAX DISTORTION =',E15.7, 0040
2' MAX D-TIME =',E15.7) 0041
512 FORMAT(1HC,' OUTPUT PARAMETERS') 0042
514 FORMAT(1HC,' DETAILED FULL ACCURACY PRINTOUT EVERY ',I3, 0043
1' CYCLE UNTIL',I6,' PRINTOUT') 0044
516 FORMAT(1HC,' LIMITED ACCURACY DISPLAY PRINTOUT OF 2D RESULTS EVERY 0045
1',I3,' CYCLE') 0046
518 FORMAT(1HC,' PICTURE DISPLAY EVERY ',I3,' CYCLE') 0047
520 FORMAT(1H0,' INITIAL WMAX=',E15.7,' D-TIME=',E15.7) 0048
522 FORMAT(1HC,' CHANGED WMAX=',E15.7,' D-TIME=',E15.7) 0049
524 FORMAT(1HC,' AT CYCLE',I5,' TIME=',E15.7,' D-TIME=',E15.7, 0050
1' DISTORT=',E15.7,' AT ZONE ',2I4,' WMAX=',E15.7,' AT ZONE ',2I4) 0051
526 FORMAT(/////' HYDRODYNAMICS ERROR STOP') 0052
528 FORMAT(1HC,' CALCULATED WMAX=',E15.7,' D-TIME=',E15.7) 0053
530 FORMAT(1HC,' ADJUSTED WMAX=',E15.7,' D-TIME=',E15.7) 0054
532 FORMAT(1H0,' STOP WMAX GREATER THAN 0.14') 0055

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534 FORMAT(1H1,5HCYCLE,5X,4HTIME,7X,10HPLUG FORCE,2X,12HPRESSURE AT , 0056
      12I3,5(8X,2I3)) 0057
536 FORMAT(I6,2E14.6,4X,6E14.6) 0058
DO 20 I=1,3000 0059
R(I)=0. 0060
Z(I)=0. 0061
RDOT(I)=0. 0062
ZDOT(I)=0. 0063
R0(I)=0. 0064
Z0(I)=0. 0065
MZERO(I)=C. 0066
E(I)=0. 0067
P(I)=0. 0068
RH0(I)=0. 0069
VP(I)=0. 0070
SC(I)=0. 0071
SSR(I)=0. 0072
SSZ(I)=0. 0073
SST(I)=0. 0074
SDR(I)=0. 0075
SDZ(I)=0. 0076
SDT(I)=0. 0077
SRZ(I)=0. 0078
STR(I)=0. 0079
STZ(I)=0. 0080
KTX(I)=0. 0081
SSRZ(I)=0. 0082
KTY(I)=0. 0083
20 CONTINUE 0084
DO 25 I=1,20 0085
PO(I)=0. 0086
EO(I)=0. 0087
GO(I)=0. 0088
CO(I)=0. 0089
AA(I)=0. 0090
BB(I)=0. 0091
CC(I)=0. 0092
CRHO(I)=0. 0093
CE(I)=0. 0094
CP(I)=0. 0095
CY0(I)=0. 0096
CNU(I)=0. 0097
VO(I)=0. 0098
CCP(I)=0. 0099
CCK(I)=0. 0100
CPLG(I)=0.0 0101
CWB(I)=0. 0102
CWN(I)=0. 0103
DO 25 J=1,50 0104
PP(I,J)=0. 0105
VV(I,J)=0. 0106
25 CONTINUE 0107
DO 26 J=1,50 0108
CIJ(J)=0. 0109
CX(J)=0. 0110

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CV(J)=0.          0111
CXD(J)=0.         0112
CVC(J)=0.         0113
KI1(J)=0          0114
KI2(J)=0          0115
KJ1(J)=0          0116
KJ2(J)=0          0117
26 CONTINUE       0118
DO 27 I=1,1000    0119
KXI(I)=0          0120
KXJ(I)=0          0121
KXYP(I)=0         0122
CXIJ(I)=0.        0123
PLGF(I)=0.        0124
TME(I)=0.         0125
DO 27 J=1,6       0126
PRS(J,I)=C.       0127
27 CCNTINUE      0128
READ 500,(TITLE(I),I=1,18) 0129
C INITIAL CONFIGURATION 0130
READ 502,IMAX,JMAX,KB1,KB2,KB3,TIME,DELT,DELTM 0131
C LIMITING CRITERIA CONSTANTS 0132
READ 503,CYCLM,TMAX,DISTM,CE1,DE2 0133
TIN=TIME          0134
IF(CYCLM)E0,40,60 0135
40 CYCLM=10000.   0136
60 IF(TMAX)1C0,8C,100 0137
80 TMAX=1000C.    0138
100 IF(DISTM)120,110,120 0139
110 DISTM=1000C.   0140
C OUTPUT CONSTANTS 0141
120 READ 504,IOUA,INUMBA,IOUB,IOUC,IOUT 0142
JQQ=IOUB          0143
MCYCL=CYCLM       0144
CX1=1.            0145
CX2=1.            0146
CX3=1.            0147
IF(KB1.EQ.0)GO TO 122 0148
CX1=-1.           0149
122 IF(KB2.EQ.0)GO TO 124 0150
CX2=-1.           0151
124 IF(KB3.EQ.0)GO TO 126 0152
CX3=-1.           0153
126 CONTINUE       0154
IF(DE1.NE.0.0)GO TO 128 0155
DE1=0.001          0156
DE2=0.005          0157
128 CONTINUE       0158
PRINT 506,(TITLE(I),I=1,18) 0159
PRINT 5C8,IMAX,JMAX,DELT 0160
PRINT 510,MCYCL,TMAX,DISTM,DELTM 0161
PRINT 512          0162
IF(IOUA)140,140,130 0163
130 PRINT 514,IOUA,INUMBA 0164
INUMBA=INUMBA-1    0165

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140 IF(IOUB)160,160,150          0166
150 PRINT 516,IOUB              0167
160 IF(IOUC)180,180,170          0168
170 PRINT 518,IOUC              0169
180 CCNTINUE
    IMAX1=IMAX+1                0170
    IMAX2=IMAX+2                0171
    IMAX3=IMAX+3                0172
    JMAX1=JMAX+1                0173
    JMAX2=JMAX+2                0174
    JMAX3=JMAX+3                0175
    IP1=2                        0176
    IP2=26                       0177
    IX=IMAX1/25                 0178
    IF(IX)186,186,182           0179
182 DO 184 I=1,IX
    I11(I)=IP1                 0180
    I12(I)=IP2                 0181
    I21(I)=IP1                 0182
    I22(I)=IP2                 0183
    IP1=IP1+25                 0184
    IP2=IP2+25                 0185
184 CCNTINUE
186 IXX=IMAX1-IX*25             0186
    IF(IXX)190,190,188           0187
188 I1X=IX+1
    I2X=I1X                     0188
    I11(I1X)=IP1               0189
    I12(I1X)=IMAX1              0190
    I21(I2X)=IP1               0191
    I22(I2X)=IMAX2              0192
    GO TO 192
190 I1X=IX
    I2X=IX+1                     0193
    I21(I2X)=IP1               0194
    I22(I2X)=IMAX2              0195
192 JP1=2
    JP2=51                       0196
    JX=JMAX1/50                 0197
    IF(JX)198,198,194           0198
194 DO 196 I=1,JX
    J11(I)=JP1                 0199
    J12(I)=JP2                 0200
    J21(I)=JP1                 0201
    J22(I)=JP2                 0202
    JP1=JP1+5C                  0203
    JP2=JP2+5C                  0204
196 CCNTINUE
198 JXX=JMAX1-JX*50             0205
    IF(JXX)202,202,200           0206
200 J1X=JX+1
    J2X=J1X                     0207
    J11(J1X)=JP1               0208
    J12(J1X)=IMAX1              0209
    J21(J2X)=JP1               0210
                                0211
                                0212
                                0213
                                0214
                                0215
                                0216
                                0217
                                0218
                                0219
                                0220

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J22(J2X)=JMAX2          0221
GO TO 204               0222
202 J1X=JX               0223
J2X=JX+1                0224
J21(J2X)=JP1            0225
J22(J2X)=JMAX2          0226
204 CONTINUE             0227
DO 208 I=1,120          0228
KK(I)=I                 0229
208 CCNTINUE             0230
ITIMA=0                  0231
NCL=0                    0231
ISTOP=0                 0232
NCYCL=0                 0233
IQQ=0                    0234
LAST=-1                 0235
IF(IOUT-1)215,215,210   0236
210 CALL OTAPE (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY,IOUT)
TIN=TIME                0237
GO TO 470               0238
215 CCNTINUE             0239
CALL HYDROI(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY) 0240
IF(IOUT.EC.0)GO TO 220   0241
CALL PICT(R,Z,P,LAST)   0242
220 INDEXA=1              0243
IF(IOUA)240,240,650     0244
240 IF(IOUB)260,260,700   0245
260 PRINT 520,WMAX,DELT  0246
280 IF(WMAX.LT.0.14)GO TO 300 0247
DELT=0.5*DELT            0248
WMAX=0.25*WMAX           0249
PRINT 522,WMAX,DELT     0250
GO TO 280               0251
300 IF(WMAX.GT.0.035)GO TO 350 0252
IF(DELT.GT.0.5*DELM)GO TO 350 0253
DELT=2.0*DELT            0254
WMAX=4.0*WMAX             0255
PRINT 522,WMAX,DELT     0256
GO TO 300               0257
350 CALL HYDRO (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ,SST,
1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY) 0258
IF(DABS(EZERC-EB)/ZERO.LT.DE1)GO TO 360 0259
IOUA=1                  0260
INUMBA=MCYCL             0261
IF(DABS(EZERO-EB)/ZERO.GT.DE2)ISTOP=1 0262
360 CONTINUE             0263
NCYCL=NCYCL+1            0264
PRINT 524,NCYCL,TIME,DELT,DIST,IDM,JDM,WMAX,IW,JW 0265
IF(ISTOP.EQ.0)GO TO 370 0266
GO TO 450               0267
370 INDEXA=2              0268
IF(IOUA.EQ.0)GO TO 375   0269
IF(MOD(NCYCL,ICUA).EQ.0.AND.ITIMA.LE.INUMBA)GO TO 380 0270
                                0271
                                0272
                                0273
                                0274

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375 CONTINUE          0275
INDEXB=0             0276
GO TO 390            0277
380 ITIMA=ITIMA+1    0278
INDEXB=1             0279
GO TO 650            0280
390 IF(IQUB.EC.0)GO TO 400 0281
IF(MOD(NCYCL,ICUB).EQ.0)GO TO 700 0282
400 IF(IQUC.EC.0)GO TO 405 0283
IF(MOD(NCYCL,IQUC).EQ.0) 0284
1CALL PICT(R,Z,P, LAST) 0285
405 CONTINUE          0286
410 IF(NCYCL-MCYCL)420,450,450 0287
420 IF(TIME - TMAX)430,450,450 0288
430 IF(DIST - DISTM)470,450,450 0289
450 LAST=1            0290
IF(IQUB.EQ.0)GO TO 455 0291
INDEXA=3             0292
GO TO 700            0293
455 CONTINUE          0294
IF(IQUC.NE.0)         0295
1CALL PICT(R,Z,P, LAST) 0296
IF(INDEXB.EQ.1.OR.IQUA.EQ.0)GO TO 750 0297
INDEXA=3             0298
GO TO 650            0299
470 CONTINUE          0300
475 IF(WMAX.GT.20.0)GO TO 490 0301
IF(WMAX.LT.0.14)GO TO 480 0302
DELT=0.5*DELT        0303
WMAX=0.25*WMAX       0304
PRINT 530,WMAX,DELT 0305
GO TO 475            0306
480 IF(WMAX.GT.0.035)GO TO 350 0307
IF(DELT.GT.(0.5*DELM))GO TO 350 0308
DELT=2.0*DELT        0309
WMAX=4.0*WMAX        0310
PRINT 530,WMAX,DELT 0311
GO TO 480            0312
490 PRINT 532          0313
GO TO 450            0314
650 CONTINUE          0315
CALL PRINTF(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZD,SC,SSR,SSZ,SST, 0316
1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY) 0317
GO TO (24C,390,750),INDEXA 0318
700 CONTINUE          0319
CALL PRINTL(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZD,SC,SSR,SSZ,SST, 0320
1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY) 0321
GO TO (26C,400,455),INDEXA 0322
750 CONTINUE          0323
IF(NPP.LE.0)GC TO 777 0324
PRINT 534,(KXP(L),KYP(L),L=1,NPP) 0325
DO 776 I=1,NCL        0326
PRINT 536,KXYP(I),TME(I),PLGF(I),(PRS(L,I),L=1,NPP) 0327
776 CONTINUE          0328
GO TO 779            0329

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777 CONTINUE
  IF(KPL1.LE.0)GO TO 779
  PRINT 535
535 FORMAT(1H1,5HCYCLE,5X,4HTIME,7X,10HPLUG FORCE)
  DO 778 I=1,NCL
  PRINT 536,KXYP(I),TME(I),PLGF(I)
778 CCNTINUE
779 CONTINUE
  CALL CALC(NCL,NPP,KPL1,KXP,KYP,TME,PLGF,PRS,TITLE,TIN)
  IF(IOUT-1)770,760,770
760 CALL OTAPE (R,Z,RDOT,ZDCT,MZERO,P,VP,E,RHO,RO,Z0,SC,SSR,SSZ,SST,
  1SSRZ,SDR,SDZ,SDT,SRZ,STR,STZ,KTX,KTY,IOUT)
770 STOP
  END

SUBROUTINE CALC(NCL,NPP,KPL1,KXP,KYP,TME,PLGF,PRS,TITLE,TIN)
DIMENSION KXP(20),KYP(20),TME(1000),PLGF(1000),PRS(6,1000),
1DATA(1000),TITLE(18),CXY(1000)
DIMENSION U1(2),U2(3),U3(5),U4(5),U6(4),U7(2),U5(2)
DIMENSION SCTK(10)
DATA U1/' TIME '//,U2//PLUG FORCE//,U3//AXIAL DISPLACEMENT//,
1U4//RADIAL DISPLACEMENT//,U5//AT ZUNE//,U6//AT MESH POINT//,
2U7//PRESSURE//'
501 FORMAT(16,(6F12.0))
502 FORMAT(16,7E15.7)
  IF(NPP.NE.0)GO TO 16
  READ 501,KCAL,SCT,SCT1
  PRINT 502,KCAL,SCT,SCT1
  GO TO 18
16 CCNTINUE
  READ 501,KCAL,SCT,SCT1,(SCTK(K),K=1,NPP)
  PRINT 502,KCAL,SCT,SCT1,(SCTK(K),K=1,NPP)
18 CONTINUE
  IF(KCAL)20,200,20
20 CALL PLOTS(DATA(1),4000,49)
  CALL PLOT(5.0,C,-3)
  CALL SYMBCL(C,5.0,0.14,TITLE(1),0,72)
  CALL PLOT(11.0,0,-3)
  IF(SCT.LE.0.0)SCT=.0001
  XMAX=(TME(NCL)-TIN)/SCT
  IF(KPL1)6C,60,30
30 CALL AXIS(0,0,U1,-8,XMAX,0,TIN,SCT,10.0)
  CALL SCALE(PLGF,10.0,NCL,1,10.0)
  PMIN=PLGF(NCL+1)
  PDEL=PLGF(NCL+2)
  IF(SCT1.NE.0.0)PDEL=SCT1
  CALL AXIS(0,0,U2,10,10.0,90.0,PMIN,PDEL,10.0)
  X=0.
  Y=(PLGF(1)-PMIN)/PDEL
  IF(Y.GE.1C-0)Y=10.0
  CALL PLOT(X,Y,3)

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DO 50 I=1,NCL          0380
X=(TME(I)-TIN)/SCT    0381
Y=(PLGF(I)-PMIN)/FDEL 0382
IF(Y.GE.10.0)Y=10.0     0383
CALL PLOT(X,Y,2)        0384
50 CONTINUE              0385
      KNEW=XMAX+2.       0386
      XNEW=KNEW            0387
      CALL PLCT(XNEW,0,-3) 0388
      IF(NPP)18C,180,60    0389
60 DO 150 L=1,NPP       0390
      DO 70 I=1,NCL        0391
      CXY(I)=PRS(L,I)      0392
70 CONTINUE              0393
      CALL SCALE(CXY,10.0,NCL,1,10.0) 0394
      FMIN=CXY(NCL+1)       0395
      FDEL=CXY(NCL+2)       0396
      IF(SCTK(L).NE.0.0)FDEL=SCTK(L) 0397
      IF(KXP(L).GT.0)GO TO 80        0398
      CALL SYMBCL(0,5.0,0.14,U4,0.0,19) 0399
75 CALL SYMBCL(0,4.5,0.14,U6,0.0,13) 0400
      KXPL=IABS(KXP(L))        0401
      KYPL=IABS(KYP(L))        0402
      CALL NUMBER(1.8,4.5,0.14,FLOAT(KXPL),0.0,-1) 0403
      CALL NUMBER(2.4,4.5,0.14,FLOAT(KYPL),0.0,-1) 0404
      GO TO 100               0405
80 IF(KYP(L).GT.0)GO TO 90        0406
      CALL SYMBCL(0,5.0,0.14,U3,0.0,18) 0407
      GO TO 75               0408
90 CALL SYMBCL(0,5.0,0.14,U7,0.0,8) 0409
      CALL SYMBCL(0,4.5,0.14,U5,0.0,7) 0410
      CALL NUMBER(1.0,4.5,0.14,FLOAT(KXP(L)),0.0,-1) 0411
      CALL NUMBER(1.5,4.5,0.14,FLOAT(KYP(L)),0.0,-1) 0412
100 CALL PLOT(3.0,0.0,-3)        0413
      CALL AXIS(0,0,U1,-8,XMAX,0,TIN,SCT,10.0) 0414
      CALL AXIS(0,0,2H ,2,10.0,90.0,FMIN,FDEL,10.0) 0415
      X=0.                  0416
      Y=(CXY(1)-FMIN)/FDEL 0417
      IF(Y.GE.10.0)Y=10.0     0418
      CALL PLOT(X,Y,3)        0419
      DO 120 I=1,NCL        0420
      X=(TME(I)-TIN)/SCT    0421
      Y=(CXY(I)-FMIN)/FDEL 0422
      IF(Y.GE.10.0)Y=10.0     0423
      CALL PLOT(X,Y,2)        0424
120 CCNTINUE              0425
      KNEW=XMAX+2.          0426
      XNEW=KNEW            0427
      CALL PLOT(XNEW,0,-3)   0428
150 CONTINUE              0429
180 CALL PLOT(0,0,999)      0430
200 CONTINUE              0431
      RETURN                0432
      END                   0433

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SUBROUTINE OTAPE (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RC,ZO,SC,SSR,SSZ, 0434
1SS,SSRZ,SDR,SCZ,SDT,SRZ,STR,STZ,KTX,KTY,IOUT) 0435
IMPLICIT REAL*8(A-H,O-Z) 0436
DIMENSION K1(50),K2(50),KZ1(50),KZ2(50),KTM(50),CRHO(20), 0437
1CE(20),CP(20),KT1(20),KT2(20) 0438
DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3), 0439
1ZDOT(IMAX3,JMAX3),RO(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX 0440
23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3), 0441
3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3) 0442
DIMENSION TITLE(20) 0443
DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3) 0444
DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SDT(IMAX3,JMAX3),SRZ(I 0445
1MAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3) 0446
1DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GU(20),CO(20), 0447
1AA(20),PB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20) 0448
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20) 0449
DIMENSION CYC(20),CNU(20) 0450
DIMENSCN CIJ(50),CXIJ(1000) 0451
CCMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL, 0452
1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDI,M,JD,M,NPP,NCL 0453
2,KXP(20),KYP(20),KXY(1000) 0454
COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2 0455
CCMON KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000) 0456
COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PU,EO,GO,CO,AA,BB, 0457
1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS 0458
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYD,CNU,CIJ,CXIJ 0459
3,PLGF(1000),TME(1000),PRS(6,1000) 0460
REAL*4 TME,PLCF,PRS,TIN 0461
REAL*4 TITLE 0462
REAL*8 MZERO 0463
INTEGER*2 KTX,KTY 0464
REWIND 8 0465
REWIND 9 0466
GO TO (10C,200,300),ICUT 0467
100 WRITE (8)NCYCL,TIME,DELT,DIST,DELTO,WMAX,IW,JW,KB1,KB2,KB3, 0468
1IQQ,JQQ,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG,CPLG 0469
WRITE(8)R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,KTX,KTY, 0470
1PP,VV,PO,EO,GO,CO,AA,BB,CC,VO,SSR,SSZ,SST,CCP,CCK,KXI,KXJ 0471
2,CV,CVD,CX,CXD,CRHO,CE,CP,EZERO,CWB,CWN,IDI,JD 0472
3,SDR,SDZ,SRZ,STR,STZ,SSRZ,CIJ,CXIJ,CNU,CYD,KXP,KYP,KXY 0473
END FILE E 0474
GO TO 450 0475
200 CONTINUE 0476
220 READ (9)NCYCL,TIME,DELT,DIST,DELTO,WMAX,IW,JW,KB1,KB2,KB3, 0477
1IQQ,JQQ,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG,CPLG 0478
READ (9)R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,KTX,KTY, 0479
1PP,VV,PO,EO,GC,CO,AA,BB,CC,VO,SSR,SSZ,SST,CCP,CCK,KXI,KXJ 0480
2,CV,CVD,CX,CXD,CRHO,CE,CP,EZERO,CWB,CWN,IDI,JD 0481
3,SDR,SDZ,SRZ,STR,STZ,SSRZ,CIJ,CXIJ,CNU,CYD,KXP,KYP,KXY 0482
GO TO 450 0483
300 ICUT=1 0484
GO TO 220 0485
450 RETURN 0486
END 0487

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SUBROUTINE HYDROI(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RO,ZU,SC,SSR,SSZ, 0488
1 SSZ,SSRZ,SDR,SCZ,SDT,SRZ,STR,STZ,KTX,KTY) 0489
IMPLICIT REAL*8(A-H,O-Z) 0490
DIMENSION KRI(50),KR2(50),KZ1(50),KZ2(50),KTM(50),CRHO(20), 0491
1 ICE(20),CP(20),KT1(20),KT2(20) 0492
DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3), 0493
1 ZDOT(IMAX3,JMAX3),R0(IMAX3,JMAX3),Z0(IMAX3,JMAX3),MZERO(IIMAX3,JMAX 0494
23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3), 0495
3 SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3) 0496
DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3) 0497
DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SUT(IMAX3,JMAX3),SRZ(I 0498
1 MAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3) 0499
DIMENSION TITLE(20) 0500
DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20), 0501
1 AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20) 0502
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20) 0503
DIMENSION CYO(20),CNU(20) 0504
DIMENSION CIJ(50),CXIJ(1000) 0505
COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL, 0506
1 INDEXA,INCEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL 0507
2,KXP(20),KYP(20),KXYP(1000) 0508
CCMOM KB1,KE2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2 0509
CCMOM K11(50),K12(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000) 0510
COMMON /A/DELT,DELTO,TIME,DIST,HMAX,TITLE,PP,VV,PO,EO,GO,CO,AA,BB, 0511
1,CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS 0512
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYO,CNU,CIJ,CXIJ 0513
3,PLGF(1000),TME(1000),PRS(6,1000) 0514
REAL*4 TME,PLGF,PRS,TIN 0515
REAL*4 TITLE 0516
REAL*8 MZERO 0517
INTEGER*2 KTX,KTY 0518
DATA PI/3.1415926536/ 0519
502 FORMAT(8F9.0) 0520
504 FORMAT(I6) 0521
506 FORMAT(12I6) 0522
508 FORMAT(6F9.0,I3) 0523
510 FORMAT(2I3,7F9.0,2I3) 0524
512 FORMAT(1HC,* ERROR IN THE INPUT CARDS  ',/' ZONE('I3,','I3, 0525
1')-R AND Z ON CARDS ARE ',2F9.3,' V.S. EXPECTED '2F9.3) 0526
514 FORMAT(1H0,* TOTAL ENERGY AT START=,E15.7) 0527
516 FORMAT(8F9.0) 0528
520 FORMAT(*0 MATERIAL CONSTANTS*) 0529
522 FORMAT(1HC,I3,6E15.7,I4) 0530
524 FORMAT(4X,8E15.7) 0531
526 FORMAT(1HC,3X,5E15.7) 0532
528 FORMAT(5I6,F12.0,2I6,F12.0) 0533
529 FORMAT(2I5,7E15.7,2I3) 0534
534 FORMAT(1HC,* PLUG CONSTANTS ',/5I6,E15.7,/18X,2I6,E15.7) 0535
C PI2=2.*PI 0536
READ R AND Z COORDINATES 0537
READ 502,(R(I,2),I=2,IMAX2) 0538
READ 502,(Z(2,J),J=2,JMAX2) 0539
DO 100 J=2,JMAX2 0540
DO 100 I=2,IMAX2 0541
R(I,J)=R(I,2) 0542

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Z(I,J)=Z(2,J)                                0543
100 CCNTINUE
      READ 504,NSEC
      PRINT 504,NSEC
      C      NSEC-NO OF RECTANGULAR SECTIONS IN THE SYSTEM 0544
      DO 120 K=1,NSEC
      READ 506,KR1(K),KR2(K),KZ1(K),KZ2(K),KT1(K),KT2(K),KTM(K) 0545
      PRINT 506,KR1(K),KR2(K),KZ1(K),KZ2(K),KT1(K),KT2(K),KTM(K) 0546
      C      120 CONTINUE
      C      KR1 AND KZ1 ARE INITIAL ZONE NUMBERS,KR2 AND KZ2 ARE FINAL 0547
      C      ZONE NUMBERS IN R AND Z DIRECTIONS-KTM IS MATERIAL CARD INDICATOR 0548
      READ 504,NMAT
      C      NMAT-NJ OF DIFFERENT MATERIAL CARDS 0549
      PRINT 520
      DO 140 K=1,NMAT
      READ 508,AA(K),BB(K),CC(K),CRHO(K),CE(K),CP(K),KKK 0550
      PRINT 522,K,AA(K),BB(K),CC(K),CRHO(K),CE(K),CP(K),KKK 0551
      READ 502,CWN(K),CWB(K),CPLG(K),CYO(K),CNU(K) 0552
      PRINT 526,CWN(K),CWB(K),CPLG(K),CYO(K),CNU(K) 0553
      IF(KKK)14C,14C,130
      130 READ 516, (PP(K,I),VV(K,I),I=1,KKK)
      PRINT 524,(PP(K,I),VV(K,I),I=1,KKK)
      READ 502,P0(K),ROK,EO(K),GO(K),CO(K)
      PRINT 526,P0(K),ROK,EO(K),GO(K),CO(K)
      VO(K)=1./ROK
      140 CCNTINUE
      C      CRHO,CE,CP,KT1,KT2 ARH THE INITIAL RHO,E,P,KTX AND KTY VALLIES 0563
      DO 250 K=1,NSEC
      L=KT1(K)
      I1=KR1(K)
      I2=KR2(K)
      J1=KZ1(K)
      J2=KZ2(K)
      IF(KTM(K))200,200,160
      160 DO 180 J=J1,J2
      DO 180 I=I1,I2
      RHO(I,J)=CRHO(L)
      E(I,J)=CE(L)
      P(I,J)=CP(L)
      RDOT(I,J)=0.
      ZDOT(I,J)=0.
      KTX(I,J)=KT1(K)
      KTY(I,J)=KT2(K)
      180 CONTINUE
      GO TO 250
      200 CCNTINUE
      C      CARD INPUT FOR THE CORE SECTION 0588
      DO 210 J=J1,J2
      DO 210 I=I1,I2
      READ 510,II,JJ,RC1,ZC1,RDOT(I,J),ZDOT(I,J),RHO(I,J),E(I,J),P(I,J), 0589
      1 KTX(I,J),KTY(I,J) 0590
      PRINT 525,II,JJ,RC1,ZC1,RDOT(I,J),ZDOT(I,J),RHO(I,J),E(I,J),P(I,J), 0591
      1,KTX(I,J),KTY(I,J) 0592
      IF(RC1.EQ.R(I,J).AND.ZC1.EQ.Z(I,J))GO TO 210 0593
      PRINT 512,II,JJ,RC1,ZC1,R(I,J),Z(I,J) 0594
      0595
      0596
      0597

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STOP
210 CCNTINUE
250 CONTINUE
WMAX=0.
DO 260 I=2,IMAX2
R(I,1)=R(I,3)
Z(I,1)=Z(I,2)-(Z(I,3)-Z(I,2))
R(I,JMAX3)=R(I,JMAX1)
Z(I,JMAX3)=Z(I,JMAX2)+(Z(I,JMAX2)-Z(I,JMAX1))
260 CONTINUE
DO 270 J=1,JMAX3
R(1,J)=-R(3,J)
Z(1,J)=Z(3,J)
R(IMAX3,J)=R(IMAX2,J)+(R(IMAX2,J)-R(IMAX1,J))
Z(IMAX3,J)=Z(IMAX1,J)
270 CCNTINUE
DO 275 J=1,JMAX2
RHO(IMAX2,J)=RHO(IMAX1,J)
275 CCNTINUE
DO 300 J=2,JMAX1
DO 300 I=2,IMAX2
A1=0.5*((Z(I+1,J+1)-Z(I,J))*R(I+1,J)-R(I,J+1))
1-(R(I+1,J+1)-R(I,J))*Z(I+1,J)-Z(I,J+1)))
IF(I.EQ.IMAX2)GO TO 280
LX=KTX(I,J)
W=(CWN(LX)*(P(I,J)+CWB(LX))/(RHO(I,J)*A1))*(DELT/1.2)**2
IF(W.LE.WMAX)GO TO 280
WMAX=W
IW=I
JW=J
280 CCNTINUE
RBARI=0.25*(R(I,J+1)+R(I+1,J+1)+R(I+1,J)+R(I,J))
300 MZERO(I,J)=A1*RBARI*RHO(I,J)
DO 340 I=2,IMAX1
KTX(I,1)=KTX(I,2)
KTY(I,1)=KTY(I,2)
KTX(I,JMAX2)=KTX(I,JMAX1)
KTY(I,JMAX2)=KTY(I,JMAX1)
MZERO(I,1)=MZERO(I,2)
MZERO(I,JMAX2)=MZERO(I,JMAX1)
340 CCNTINUE
DO 360 J=1,JMAX2
KTX(1,J)=KTX(2,J)
KTY(1,J)=KTY(2,J)
KTX(IMAX2,J)=KTX(IMAX1,J)
KTY(IMAX2,J)=KTY(IMAX1,J)
MZERO(1,J)=MZERO(2,J)
360 CONTINUE
MZERO(IMAX2,JMAX2)=MZERO(IMAX2,JMAX1)
MZERO(IMAX2,1)=MZERO(IMAX2,2)
EZERO=0.
DO 380 J=2,JMAX2
DO 380 I=2,IMAX2
IF(I.EQ.IMAX2.OR.J.EQ.JMAX2)GO TO 370
EZERO=EZERO+PI2*MZERO(I,J)*E(I,J)
380

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370 CONTINUE          0653
  R0(I,J)=R(I,J)    0654
  Z0(I,J)=Z(I,J)    0655
380 CONTINUE          0656
  READ 528,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG 0657
  PRINT 534,KPP,KPP1,KPP2,KPPX,KPPC,PMASS,KPL1,KPL2,PLUG 0658
  IF(KPPX.LE.0)GO TO 80 0659
  READ 516,(CX(I),CXD(I),I=1,KPPX) 0660
  PRINT 524,(CX(I),CXD(I),I=1,KPPX) 0661
80 IF(KPPC.LE.0)GO TO 82 0662
  READ 516,(CV(I),CVD(I),I=1,KPPC) 0663
  PRINT 524,(CV(I),CVD(I),I=1,KPPC) 0664
82 CONTINUE          0665
86 CONTINUE          0666
  READ 504,NPP        0667
  PRINT 504,NPP       0668
  IF(NPP.LE.0)GO TO 88 0669
  READ 506,(KXP(L),KYP(L),L=1,NPP) 0670
  PRINT 506,(KXP(L),KYP(L),L=1,NPP) 0671
88 CONTINUE          0672
  PRINT 514,EZERC     0673
  DELTO=0             0674
  DIST=0.            0675
  IQQ=0              0676
  IX=0               0677
  DO 450 I=2,IMAX2   0678
  DO 450 J=2,JMAX2   0679
  LX1=KTX(I,J)       0680
  LX2=KTX(I-1,J)     0681
  LX3=KTX(I-1,J-1)   0682
  LX4=KTX(I,J-1)     0683
  IF(CPLG(LX1).EQ.0)GO TO 434 0684
  IF(CPLG(LX2).EQ.0)GO TO 428 0685
  IF(CPLG(LX3).EQ.0)GO TO 424 0686
  IF(CPLG(LX4).EQ.0)GO TO 422 0687
  GO TO 450           0688
422 IX=IX+1          0689
  KX1(IX)=I           0690
  KXJ(IX)=J           0691
  CXIJ(IX)=3.         0692
  GO TO 450           0693
424 IF(CPLG(LX4).NE.0)GO TO 422 0694
426 IX=IX+1          0695
  KX1(IX)=I           0696
  KXJ(IX)=J           0697
  CXIJ(IX)=2.         0698
  GO TO 450           0699
428 IF(CPLG(LX3).NE.0)GO TO 422 0700
  IF(CPLG(LX4).NE.0)GO TO 426 0701
432 IX=IX+1          0702
  KX1(IX)=I           0703
  KXJ(IX)=J           0704
  CXIJ(IX)=1.         0705
  GO TO 450           0706
434 IF(CPLG(LX2).NE.0)GO TO 436 0707

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IF(CPLG(LX3).NE.0)GO TO 438 0708
IF(CPLG(LX4).NE.0)GO TO 432 0709
GO TO 450 0710
436 IF(CPLG(LX3).EQ.0)GO TO 432 0711
IF(CPLG(LX4).EQ.0)GO TO 426 0712
GO TO 422 0713
438 IF(CPLG(LX4).EQ.0)GO TO 432 0714
GO TO 426 0715
450 CONTINUE 0716
IQQ=IX 0717
RETURN 0718
END 0719

SUBROUTINE HYDRO (R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHU,RO,ZU,SC,SSR,SSZ,
1 SSTS,SSRZ,SDR,SCZ,SDT,SRZ,STR,STZ,KTX,KTY) 0720
IMPLICIT REAL*8(A-H,O-Z) 0721
DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3) 0722
1 ZDOT(IMAX3,JMAX3),R0(IMAX3,JMAX3),ZU(IMAX3,JMAX3),MZEROU(IMAX3,JMAX
23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3),
3 SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3) 0724
DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IIMAX3,JMAX3) 0725
DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SDT(IMAX3,JMAX3),SRZ(I
1 IMAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3) 0726
DIMENSION TITLE(20) 0727
DIMENSION PP(20,50),VV(20,50),PO(20),EU(20),GO(20),CO(20), 0728
1 AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20) 0729
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20) 0730
DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20) 0731
DIMENSION CIJ(50),CXIJ(1000) 0732
COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL, 0733
1 INDEXA,INCEXB,IW,JW,ISTUP,IQQ,JQQ,IMD,JDM,NPP,NCL 0734
2,KXP(20),KYP(20),KXYP(1000) 0735
COMMON KB1,KB2,KB3,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2 0736
COMMON KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000) 0737
COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,ED,GO,CO,AA,BB,
1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS 0738
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYD,CNU,CIJ,CXIJ 0739
3,PLGF(100C),TME(1000),PRS(6,1000) 0740
REAL*4 TME,PLGF,PRS,TIN 0741
REAL*4 TITLE 0742
REAL*8 MZERO 0743
INTEGER*2 KTX,KTY 0744
DATA PI/3.1415926536/ 0745
504 FORMAT(' PRESSURE-ENERGY ITERATION HAS NOT CONVERGED FOR POINT',
1215) 0746
506 FORMAT(1HC,7X,'TIME INTERNAL ENERGY KINETIC ENERGY',3X,
1'TOTAL ENERGY',/4E15.7) 0747
512 FORMAT(5X,' FORCE ON PLUG EXCEEDS ALLOWABLE VALUE ',2E15.7) 0748
513 FORMAT(5X,' ALLCWALE STRAIN IS EXCEEDED') 0749
517 FORMAT(2I6,8E14.6,/12X,8E14.6) 0750
519 FORMAT(' PLASTICITY EXISTS AT ZONE ',2I3,' FAILURE INDEX =',E15.7) 0751

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PI04=PI/4.          0758
PI2=PI*2.          0759
PI02=PI/2.          0760
TKE=0.              0761
TIE=0.              0762
WMAX=0.             0763
SCOUND=2.5E5        0764
UEP=1.0             0765
REP=1.0E-6          0766
PEP=1.0E-4          0767
DIST=0.             0768
PHP=-CYO(3)/3.     0769
DELTB=0.5*(DELTG+DELT) 0770
TM=TIME+0.5*DELT   0771
TIME=TIME+DELT     0772
DELTO=DELT          0773
DO 40 I=2,IMAX2     0774
R(I,1)=R(I,3)        0775
Z(I,1)=Z(I,2)-(Z(I,3)-Z(I,2)) 0776
R(I,JMAX3)=R(I,JMAX1) 0777
Z(I,JMAX3)=Z(I,JMAX2)+(Z(I,JMAX2)-Z(I,JMAX1)) 0778
40 CONTINUE          0779
DO 60 J=1,JMAX3     0780
R(1,J)=-R(3,J)      0781
Z(1,J)=Z(3,J)        0782
R(IMAX3,J)=R(IMAX2,J)+(R(IMAX2,J)-R(IMAX1,J)) 0783
Z(IMAX3,J)=Z(IMAX1,J) 0784
60 CONTINUE          0785
DO 80 I=2,IMAX1      0786
RHO(I,1)=RHO(I,2)    0787
P(I,1)=CX3*P(I,2)    0788
SDR(I,1)=CX3*SDR(I,2) 0789
SDZ(I,1)=CX3*SDZ(I,2) 0790
SDT(I,1)=CX3*SDT(I,2) 0791
SRZ(I,1)=-SRZ(I,2)    0792
RHO(I,JMAX2)=RHC(I,JMAX1) 0793
P(I,JMAX2)=CX1*P(I,JMAX1) 0794
SDR(I,JMAX2)=CX1*SDR(I,JMAX1) 0795
SDZ(I,JMAX2)=CX1*SDZ(I,JMAX1) 0796
SDT(I,JMAX2)=CX1*SDT(I,JMAX1) 0797
SRZ(I,JMAX2)=-SRZ(I,JMAX1) 0798
80 CONTINUE          0799
DO 100 J=1,JMAX2     0800
RHO(1,J)=RHO(2,J)    0801
P(1,J)=P(2,J)        0802
SDR(1,J)=SDR(2,J)    0803
SDZ(1,J)=SDZ(2,J)    0804
SDT(1,J)=SDT(2,J)    0805
SRZ(1,J)=SRZ(2,J)    0806
RHO(IMAX2,J)=RHC(IMAX1,J) 0807
P(IMAX2,J)=CX2*P(IMAX1,J) 0808
SDR(IMAX2,J)=CX2*SDR(IMAX1,J) 0809
SDZ(IMAX2,J)=CX2*SDZ(IMAX1,J) 0810
SDT(IMAX2,J)=CX2*SDT(IMAX1,J) 0811
SRZ(IMAX2,J)=-SRZ(IMAX1,J) 0812

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100 CONTINUE
C LOOP 140 TO CALCULATE VELOCITIES AND ACCELERATIONS      0813
DO 140 J=2,JMAX2                                         0814
DO 140 I=2,IMAX2                                         0815
CTD1=.25*DABS(R(I,J+1)+R(I+1,J+1)+R(I+1,J)+R(I,J))    0816
CTD2=.25*DABS(R(I-1,J+1)+R(I,J+1)+R(I,J)+R(I-1,J))    0817
CTD3=.25*DABS(R(I-1,J)+R(I,J)+R(I,J-1)+R(I-1,J-1))   0818
CTD4=.25*DABS(R(I,J)+R(I+1,J)+R(I+1,J-1)+R(I,J-1))   0819
CONST=1./(MZERC(I,J)/CTD1+MZERO(I-1,J)/CTD2+MZERO(I-1,J-1)/CTD3 0820
1+MZERO(I,J-1)/CTD4)                                     0821
P1=P(I,J)-P(I-1,J-1)                                    0822
P2=P(I-1,J)-P(I,J-1)                                    0823
P4=-P2                                                 0824
IF(SRZ(I,J).NE.0.0.OR.SRZ(I-1,J).NE.0.0.OR.SRZ(I,J-1).NE.0.0.OR. 0825
1SRZ(I-1,J-1).NE.0.0)GO TO 94                           0826
KL=2                                                 0827
GO TO 96                                               0828
94 KL=1                                               0829
96 CONTINUE
GO TO (101,103),KL                                     0830
101 CONTINUE
A1=-.5*((R(I,J+1)-R(I+1,J))*(Z(I+1,J+1)-Z(I,J))-(R(I+1,J+1)-R(I,J) 0831
1)*Z(I,J+1)-Z(I+1,J)))                                0832
A2=-.5*((R(I-1,J+1)-R(I,J))*(Z(I,J+1)-Z(I-1,J))-(R(I,J+1)-R(I-1,J) 0833
1)*Z(I-1,J+1)-Z(I,J)))                                0834
A3=-.5*((R(I-1,J)-R(I,J-1))*(Z(I,J)-Z(I-1,J-1))-(R(I,J)-R(I-1,J-1) 0835
1)*(Z(I-1,J)-Z(I,J-1)))                                0836
A4=-.5*((R(I,J)-R(I+1,J-1))*(Z(I+1,J)-Z(I,J-1))-(R(I+1,J)-R(I,J-1) 0837
1)*(Z(I,J)-Z(I+1,J-1)))                                0838
CDDD=0.25*((2.*SDR(I,J)+SDZ(I,J))*A1/MZERO(I,J)+(2.*SDR(I-1,J)+ 0839
1SDZ(I-1,J))*A2/MZERO(I-1,J)+(2.*SDR(I-1,J-1)+SDZ(I-1,J-1))*A3/ 0840
2MZERO(I-1,J-1))+((2.*SDR(I,J-1)+SDZ(I,J-1))*A4/MZERO(I,J-1))     0841
CDD=0.25*(SRZ(I,J)*A1/MZERO(I,J)+SRZ(I-1,J)*A2/MZERO(I-1,J)+ 0842
1SRZ(I-1,J-1)*A3/MZERO(I-1,J-1)+SRZ(I,J-1)*A4/MZERO(I,J-1))     0843
R1=R(I+1,J)-R(I-1,J)                                 0844
R2=R(I,J-1)-R(I,J+1)                                0845
Z1=Z(I+1,J)-Z(I-1,J)                                0846
Z2=Z(I,J-1)-Z(I,J+1)                                0847
R13=R1+R2                                         0848
Z13=Z1+Z2                                         0849
R24=R1-R2                                         0850
Z24=Z1-Z2                                         0851
SRZ1=SRZ(I,J)-SRZ(I-1,J-1)                         0852
SRZ4=SRZ(I,J-1)-SRZ(I-1,J)                         0853
IF(IQQ.EQ.0)GO TO 119                               0854
DO 112 K=1,IQQ                                      0855
IF(I.EQ.KXI(K).AND.J.EQ.KXJ(K))GO TO 116          0856
112 CONTINUE
GO TO 119                                           0857
116 CDDD=CDDD*4./CXIJ(K)
CDD=CDD*4./CXIJ(K)
119 CONTINUE
103 CONTINUE
IF(I.EQ.2)GO TO 110
IF(I.NE.IMAX2)GO TO 108

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IF(KPP.EQ.2)GO TO 110          0868
IF(KB2.EQ.0)GO TO 110          0869
108 CONTINUE                   0870
   GO TO (105,107),KL          0871
105 CONTINUE                   0872
   RDDOT=-CONST*(P4*Z24-P1*Z13-((SDR(I,J-1)-SDR(I-1,J))*Z24
      1-(SDR(I,J)-SDR(I-1,J-1))*Z13)+SRZ4*R24-SRZ1*R13)+CDDO
   GO TO 109                   0873
107 CONTINUE                   0874
   RDDOT=-CONST*(P1*(Z(I,J+1)-Z(I,J-1)+Z(I-1,J)-Z(I+1,J))
      1-P2*(Z(I,J+1)-Z(I,J-1)+Z(I+1,J)-Z(I-1,J)))          0875
109 CONTINUE                   0876
   RDB=RDDOT*DELTB             0877
   IF(DABS(RDB).LT.UEP)GO TO 110          0878
   RDOT(I,J)=RDDOT(I,J)+RDB          0879
110 CONTINUE                   0880
   IF(J.NE.JMAX2)GO TO 122          0881
   IF(KPP.EQ.1)GO TO 140          0882
   IF(KB1.EQ.0)GO TO 140          0883
   GO TO 124                   0884
122 IF(J.NE.2)GO TO 124          0885
   IF(KPP.EQ.3)GO TO 140          0886
   IF(KB3.EQ.0)GO TO 140          0887
124 CCNTINUE                  0888
   GO TO (125,127),KL          0889
125 CONTINUE                   0890
   ZDDOT=CONST*(P4*R24-P1*R13-((SDZ(I,J-1)-SDZ(I-1,J))*K24
      1-(SDZ(I,J)-SDZ(I-1,J-1))*R13)+SRZ4*Z24-SRZ1*Z13)+CDD
   GO TO 129                   0891
127 CCNTINUE                  0892
   ZDDOT=CONST*(P1*(R(I,J+1)-R(I,J-1)+R(I-1,J)-R(I+1,J))
      2-P2*(R(I,J+1)-R(I,J-1)+R(I+1,J)-R(I-1,J)))          0893
129 CCNTINUE                  0894
   ZDB=ZDDOT*DELTB             0895
   IF(DABS(ZDB).LT.UEP)GO TO 140          0896
   ZDOT(I,J)=ZDOT(I,J)+ZDB          0897
140 CONTINUE                   0898
C END CF LOOP 140             0899
   IF(KPP.EQ.0)GO TO 498          0900
   TOTP=0.0                     0901
   GO TO (410,470,480),KPP          0902
410 DO 420 I=KPP1,KPP2          0903
420 TOTP=TOP+PI02*(I,JMAX1)*(R(I+1,JMAX2)**2-R(I,JMAX2)**2)
   XZ=Z(KPP1,JMAX2)-Z0(KPP1,JMAX2)          0904
   XZZ=ZDOT(KPP1,JMAX2)          0905
415 IF(KPPX.LE.0)GO TO 432          0906
   IF(XZ.GE.CXD(1))GO TO 434          0907
   DO 430 L=1,KPPX              0908
   IF(XZ-CXD(L))430,436,438          0909
430 CONTINUE                   0910
432 CXXP=0.                     0911
   GO TO 440                   0912
434 CXXP=CX(1)                 0913
   GO TO 440                   0914
436 CXXP=CX(L)                 0915

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GO TO 440                                0923
438 CXXP=CX(L-1)+(XZ -CXD(L-1))*(CX(L)-CX(L-1))/(CXD(L)-CXD(L-1)) 0924
440 CONTINUE                               0925
        IF(KPPC.LE.0) GO TO 452               0926
        IF(XZZ.GE.CVC(1)) GO TO 454          0927
        DO 450 L=1,KPPC                      0928
        IF(XZZ-CVC(L)) 450,456,458          0929
450 CCNTINUE                             0930
452 CXVP=0.                                0931
        GO TO 460                           0932
454 CXVP=CV(1)                            0933
        GO TO 460                           0934
456 CXVP=CV(L)                            0935
        GO TO 460                           0936
458 CXVP=CV(L-1)+(XZZ-CVC(L-1))*(CV(L)-CV(L-1))/(CVD(L)-CVD(L-1)) 0937
460 XDDOT=(TOTP-CXXP-CXVP)/PMASS         0938
        XCB=XDDOT*DELTB                   0939
        IF(DABS(XCB).LT.UEP) GO TO 496      0940
        GO TO (484,488,492),KPP            0941
470 DO 472 J=KPP1,KPP2                    0942
472 TOTP=TOPR+PI*R(IMAX2,J)*P(IMAX1,J)*DABS(Z(IMAX2,J+1)-Z(IMAX2,J)) 0943
        XZ=R(IMAX2,KPP1)-RO(IMAX2,KPP1)   0944
        XZ=RDOT(IMAX2,KPP1)                0945
        GO TO 415                           0946
480 DO 482 I=KPP1,KPP2                    0947
482 TOTP=TOPR+PI02*P(I,2)*(R(I+1,2)**2-R(I,2)**2)                  0948
        XZ=DABS(Z(KPP1,2)-Z0(IMAX2,2))    0949
        XZ=DABS(ZDOT(KPP1,2))              0950
        GO TO 415                           0951
484 DO 486 I=2,IMAX2                     0952
486 ZDOT(I,JMAX2)=ZDOT(I,JMAX2)+XDDOT*DELTB                         0953
        GO TO 496                           0954
488 DO 490 J=2,JMAX2                     0955
490 RDOT(IMAX2,J)=RDOT(IMAX2,J)+XDCOT*DELTB                         0956
        GO TO 496                           0957
492 DO 494 I=2,IMAX2                     0958
494 ZDOT(I,2)=ZDOT(I,2)-XDDOT*DELTB                         0959
496 CONTINUE                               0960
498 CCNTINUE                             0961
        DO 150 J=2,JMAX2                   0962
        DO 150 I=2,IMAX2                   0963
        R(I,J)=R(I,J)+RDOT(I,J)*DELT     0964
        Z(I,J)=Z(I,J)+ZDOT(I,J)*DELT    0965
        IF(J.EQ.JMAX2.OR.I.EQ.IMAX2) GO TO 150 0966
        TKE=TKE+PI04*MZERO(I,J) * (RDOT(I,J)*RDOT(I,J)+ZDOT(I,J)* 0967
        1 ZDOT(I,J)+RDOT(I,J+1)*RDOT(I,J+1)+ZDOT(I,J+1)*ZDOT(I,J+1)+ 0968
        2 RDOT(I+1,J+1)*RDOT(I+1,J+1)+ZDOT(I+1,J+1)*ZDOT(I+1,J+1)+ 0969
        3 RDOT(I+1,J)*RDOT(I+1,J)+ZDOT(I+1,J)*ZDOT(I+1,J))           0970
150 CONTINUE                               0971
C LOOP 220 TO CALCULATE ZONE QUANTITIES 0972
        DO 220 J=2,JMAX1                   0973
        DO 220 I=2,IMAX1                   0974
        DDTK=0.                            0975
        LY=KTY(I,J)                      0976
        LX=KTX(I,J)                      0977

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I1=I+1 0978
J1=J+1 0979
CDR=SDR(I,J) 0980
CDZ=SDZ(I,J) 0981
CDT=SDT(I,J) 0982
CRZ=SRZ(I,J) 0983
CDRS=SSR(I,J) 0984
CCZS=SSZ(I,J) 0985
COTS=SST(I,J) 0986
CRZS=SSRZ(I,J) 0987
R1=R(I1,J)-R(I,J) 0988
Z1=Z(I1,J)-Z(I,J) 0989
D1=R1*R1+Z1*Z1 0990
V1=(RDOT(I1,J)-RDOT(I,J))*R1+(ZDOT(I1,J)-ZDOT(I,J))*Z1 0991
R2=R(I1,J1)-R(I,J) 0992
Z2=Z(I1,J1)-Z(I,J) 0993
D2=R2*R2+Z2*Z2 0994
V2=(PDOT(I1,J1)-RDOT(I1,J))*R2+(ZDOT(I1,J1)-ZDOT(I1,J))*Z2 0995
R3=R(I,J1)-R(I1,J1) 0996
Z3=Z(I,J1)-Z(I1,J1) 0997
D3=R3*R3+Z3*Z3 0998
V3=(RDOT(I,J1)-RDOT(I1,J1))*R3+(ZDOT(I,J1)-ZDOT(I1,J1))*Z3 0999
R4=R(I,J)-R(I,J1) 1000
Z4=Z(I,J)-Z(I,J1) 1001
D4=R4*R4+Z4*Z4 1002
V4=(RDOT(I,J)-RDOT(I,J1))*R4+(ZDOT(I,J)-ZDOT(I,J1))*Z4 1003
R5=R(I1,J1)-R(I,J) 1004
Z5=Z(I1,J1)-Z(I,J) 1005
D5=R5*R5+Z5*Z5 1006
X5=RDOT(I1,J1)-RDOT(I,J) 1007
Y5=ZDOT(I1,J1)-ZDOT(I,J) 1008
V5=X5*R5+Y5*Z5 1009
R6=R(I1,J)-R(I,J1) 1010
Z6=Z(I1,J)-Z(I,J1) 1011
D6=R6*R6+Z6*Z6 1012
X6=RDOT(I1,J)-RCOT(I,J1) 1013
Y6=ZDOT(I1,J)-ZDOT(I,J1) 1014
V6=X6*R6+Y6*Z6 1015
DMST=DMAX1( DMAX1(D1,D3)/DMIN1(D1,D3),DMAX1(D2,D4)/DMIN1(D2, 1016
1D4),DMAX1(D5,D6)/DMIN1(D5,D6)) 1017
IF(DMST.LE.DIST)GO TO 162 1018
DIST=DMST 1019
IDM=I 1020
JDM=J 1021
162 CCNTINUE 1022
DELV=0.0 1023
AREA=0.5*(Z5*R6-R5*Z6) 1024
CTRD=0.25*(R(I,J)+R(I,J1)+R(I1,J)+R(I1,J1)) 1025
VCL=AREA*CTRD 1026
IF(RDOT(I,J).NE.0.0. OR.RDOT(I1,J).NE.0.0. OR.RDOT(I,J1).NE.0.0. 1027
1 OR.RDOT(I,J1).NE.0.0)GO TO 165 1028
IF(ZDOT(I,J).NE.0.0. OR.ZDOT(I1,J).NE.0.0. OR.ZDOT(I,J1).NE.0.0. 1029
1 OR.ZDOT(I,J1).NE.0.0)GO TO 165 1030
155 CCNTINUE 1031
RHOT=RHO(I,J) 1032

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PTEMP=P(I,J)
ETEMP=E(I,J)
VP1=0.
GO TO 200
165 CONTINUE
RHOT=MZERC(I,J)/VOL
DELV=1.0/RHOT-1.0/RHO(I,J)
IF(DELV.GE.0.0)GO TO 170
VP1=1.44*AREA*CRHO(LX)*RHOT*RHOT*(DELV/DELT)**2
GO TO 180
170 VP1=0
180 CCNTINUE
PSTAR=P(I,J)
IF(CPLG(LX).EQ.0.0)GO TO 186
182 CCNTINUE
A2A=AREA+AREA
DSV=(1./RHOT+1./RHO(I,J))/2.
DDLV=DELV/DSV
SNW=-((X6*R5-X5*R6)+(Y6*Z5-Y5*Z6))*DELT/(A2A*2.)
C2W=1-2.*SNW*SNW
CNW=DSQRT(1.-SNW*SNW)
S2W=2.*SNW*CNW
DROR=(X6*Z5-X5*Z6)/A2A
DRDRT=DRDR*DELT
DZDZ=(Y6*R5-Y5*R6)/A2A
DZDZT=DZDZ*DELT
DTCT=DDLV/DELT-(DRDR+DZDZ)
DTDTT=DTDT*DELT
DRDZ=((Y6*Z5-Y5*Z6)-(X6*R5-X5*R6))/A2A
DRDZT=DRDZ*DELT
SSR(I,J)=SSR(I,J)+DRDRT
SSZ(I,J)=SSZ(I,J)+DZDZT
SST(I,J)=SST(I,J)+DTDTT
SSRZ(I,J)=SSRZ(I,J)+DRDZT
DZZ=(SDZ(I,J)-SDR(I,J))*(C2W-1.)/2.-SRZ(I,J)*S2W
DRR=-DZZ
CRZ=SRZ(I,J)*(C2W-1.)+(SDZ(I,J)-SDR(I,J))*S2W/2.
UNU=2.*CNU(LX)
DDLV3=DDLV/3.
SDR(I,J)=SDR(I,J)+UNU*(DRDRT-DDLV3)+DRR
SDZ(I,J)=SDZ(I,J)+UNU*(DZDZT-DDLV3)+DZZ
SDT(I,J)=SDT(I,J)+UNU*(DTDTT-DDLV3)
SRZ(I,J)=SRZ(I,J)+CNU(LX)*DRDZT+DRZ
SJN=(SDR(I,J)**2+SDZ(I,J)**2+SDT(I,J)**2)+2.*SRZ(I,J)**2
CKJ=SJN-2.*CYO(LX)**2/3.
IF(CKJ.LE.0.)GO TO 184
PRINT 519,I,J,SJN
CKJJ=CYO(LX)*DSQRT(.666667/SJN)
SDR(I,J)=SDR(I,J)*CKJJ
SDZ(I,J)=SDZ(I,J)*CKJJ
SDT(I,J)=SDT(I,J)*CKJJ
SRZ(I,J)=SRZ(I,J)*CKJJ
184 CONTINUE
S22N=DSQRT((SDZ(I,J)-SDR(I,J))**2+(2.*SRZ(I,J))**2)/2.
S12N=(SDR(I,J)+SDZ(I,J))/2.

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STR(I,J)=S12N+S22N          1088
STZ(I,J)=S12A-S22N          1089
SXX=(SDR(I,J)+CDR)/2.       1090
SYY=(SDZ(I,J)+CDZ)/2.       1091
STT=(SDT(I,J)+CDT)/2.       1092
SXY=(SRZ(I,J)+CRZ)/2.       1093
DDTK=DDTK+(SXX*DRDRT+SYY*DZDZT+STT*DTDTT+SXY*DRDZT)*DSV 1094
IF(SSR(I,J).GE.CPLG(LX))GO TO 183 1095
IF(SSZ(I,J).GE.CPLG(LX))GO TO 183 1096
IF(SST(I,J).GE.CPLG(LX))GO TO 183 1097
IF(SSRZ(I,J).GE.CPLG(LX))GO TO 183 1098
GO TO 186 1099
183 ISTOP=2 1100
186 CONTINUE 1101
GO TO (26C,300),LY 1102
260 RATIO=1./(RHOT*VO(LX)) 1103
IF(RATIO.LE.VV(LX,1))GO TO 278 1104
DO 270 L=1,50 1105
IF(VV(LX,L).EQ.0.)GO TO 279 1106
IF(RATIO-VV(LX,L))290,280,270 1107
270 CONTINUE 1108
PH=0. 1109
GO TO 295 1110
278 PH=PP(LX,1) 1111
GO TO 295 1112
279 L=L-1 1113
280 PH=PP(LX,L) 1114
GO TO 295 1115
290 PH=PP(LX,L-1)+(RATIO-VV(LX,L-1))*(PP(LX,L)-PP(LX,L-1))/(VV(LX,L)- 1116
  VV(LX,L-1)) 1117
295 CCNTINUE 1118
HP=PH 1119
PH=PH*1.0E9 1120
IF(LX.NE.3)GO TO 297 1121
IF(HP.LE.131.)GO TO 297 1122
IF(HP.GE.321.)GO TO 298 1123
G=GO(LX)+(CO(LX)-GO(LX))*(HP-131.)/190. 1124
GO TO 299 1125
297 G=GO(LX) 1126
GO TO 299 1127
298 G=CO(LX) 1128
299 CONTINUE 1129
C EQUATION OF STATE - SOLIDS AND LIQUIDS 1130
EH=EO(LX)+0.5*(PH+PO(LX))*(VO(LX)-1./RHOT) 1131
ETEMP=(E(I,J)+DDTK-0.5*(PH-G*RHOT*EH+VP1+P(I,J))*DELV)/ 1132
  1.+.5*G*RHOT*DELV) 1133
PTEMP=PH+G*RHOT*(ETEMP-EH)+VP1 1134
GO TO 200 1135
300 CONTINUE 1136
DO 190 L=1,20 1137
ETEMP=E(I,J)+DDTK-0.5*(PSTAR+P(I,J))*DELV 1138
IF(LX.GT.1)GO TO 344 1139
C EQUATION OF STATE - ARGON 1140
PTEMP=AA(LX)*DEXP(-BB(LX)/(ETEMP+CC(LX))) 1141
GC TO 350 1142

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344 CONTINUE          1143
C   EQUATION OF STATE - CORE      1144
  PTEMP=AA(LX)*ETEMP*RHOT      1145
350 CONTINUE          1146
  PTEMP=PTEMP+VP1      1147
  IF(DABS(PTEMP-PSTAR)/DABS(PTEMP+0.001).LT.0.001)GO TO 195 1148
190 PSTAR=PTEMP      1149
  PRINT 504,I,J      1150
  ISTOP=1      1151
  RETURN      1152
195 CCNTINUE          1153
200 TIE=TIE+PI*MZERO(I,J)*(ETEMP+E(I,J))      1154
  W=(CWN(LX)*(PTEMP+CWB(LX))/(RHOT*AREA))*(DELT/1.2)**2+ 1155
  14.0*DABS(DELV*RHOT)      1156
  IF(W.LE.WMAX)GO TO 210      1157
  WMAX=W      1158
  IW=I      1159
  JW=J      1160
  AC1=AREA      1161
  AC2=RHO(I,J)      1162
  AC3=P(I,J)      1163
210 RHO(I,J)=RHOT      1164
  P(I,J)=PTEMP      1165
  E(I,J)=ETEMP      1166
  VP(I,J)=VP1      1167
220 CCNTINUE          1168
  IF(KPL1.EQ.0)GO TO 240      1169
  TPL=0.0      1170
  DO 230 I=KPL1,KPL2      1171
230 TPL=TPL+PI02*P(I,JMAX1)*(R(I+1,JMAX2)**2-R(I,JMAX2)**2) 1172
  IF(TPL.LE.PLUG)GO TO 240      1173
  PRINT 512,TPL,PLUG      1174
  ISTOP=1      1175
240 CCNTINUE          1176
  IF(ISTOP.NE.2)GO TO 245      1177
  PRINT 513      1178
  ISTOP=1      1179
245 CCNTINUE          1180
  EB=TIE+TKE      1181
  PRINT 506,TIME,TIE,TKE,EB      1182
  NCL=NCL+1      1183
  NPN=1      1184
  IF(NPP.GT.0)GO TO 243      1185
  IF(KPL1.LE.0)GO TO 249      1186
  GO TO 248      1187
243 CCNTINUE          1188
  IF(NPP.LE.0)GO TO 248      1189
  NPN=NPP      1190
  DO 247 L=1,NPP      1191
  II=IABS(KXP(L))      1192
  JJ=IABS(KYP(L))      1193
  IF(KXP(L).GT.0)GO TO 244      1194
  PRS(L,NCL)=R(II,JJ)-R0(II,JJ) 1195
  GO TO 247      1196
244 IF(KYP(L).GT.0)GO TO 246      1197

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PRS(L,NCL)=Z(II,JJ)-ZO(II,JJ)          1198
GO TO 247                               1199
246 PRS(L,NCL)=P(II,JJ)                  1200
247 CONTINUE                            1201
248 CONTINUE                            1202
PLGF(NCL)=TPL                           1203
TME(NCL)=TIME                          1204
KXYP(NCL)=NCYCL+1                      1205
PRINT 536,KXYP(NCL),TME(NCL),PLGF(NCL),(PRS(L,NCL),L=1,NPN) 1206
536 FCRMAT(I6,2E14.6,4X,6E14.6)        1207
249 CONTINUE                            1208
RETURN                                 1209
END                                     1210

SUBROUTINE PRINTF(R,Z,RDOT,ZDOT,MZERO,P,VP,E,RHO,RC,ZD,SC,SSR,SSZ, 1211
1SST,SSRZ,SDR,SEZ,SDT,SRZ,STR,STZ,KTX,KTY) 1212
IMPLICIT REAL*8(A-H,O-Z)               1213
DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDUT(IMAX3,JMAX3), 1214
1ZDOT(IMAX3,JMAX3),RO(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX 1215
23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3), 1216
3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3) 1217
DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3) 1218
DIMENSION TITLE(20)                   1219
DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GU(20),CU(20), 1220
1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20) 1221
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20) 1222
DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20) 1223
DIMENSION CIJ(50),CXIJ(1000)           1224
COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL, 1225
1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL 1226
2,KXP(20),KYP(20),KXYP(1000)         1227
COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2 1228
COMMON KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000) 1229
COMMON /A/DELT,DELT0,TIME,DIST,WMAX,TITLE,PP,VV,PU,EO,GU,CO,AA,BB, 1230
1,CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS 1231
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CY0,CNU,CIJ,CXIJ 1232
3,PLGF(1000),TME(1000),PRS(6,1000)    1233
REAL*4 TME,PLGF,PRS,TIN               1234
REAL*4 TITLE                           1235
REAL*8 MZERC                           1236
INTEGER*2 KTX,KTY                     1237
510 FCRMAT(1H ,30X,18A4//)            1238
512 FORMAT(1HC,' CYCLE NO=',I5,' AT TIME ',E15.7) 1239
514 FORMAT(1HC,' ZONE',4X,'R',14X,'Z',12X,'RADIAL VEL.',4X, 1240
1'AXIAL VEL.',5X,'PRESSURE',7X,'ENERGY',9X,'DENSITY',8X,'MASS', 1241
2 9X,'MT PH',// R Z',/) 1242
516 FCRMAT(1H ,2I3,8E15.7,I3,I2)      1243
518 FORMAT(1HC,' ZONE',4X,'R',14X,'Z',12X,'RADIAL VEL.',4X, 1244
1'AXIAL VEL.',5X,'PRESSURE',6X,'VISCOUS PRESS. ENERGY',9X,'DENSITY 1245
2',6X,'MT PH',// R Z',/) 1246

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520 FORMAT(1H1) 1247
522 FORMAT(1H ) 1248
PRINT 520 1249
PRINT 510,(TITLE(I),I=1,18) 1250
PRINT 512,NCYCL,TIME 1251
IF(NCYCL.NE.0)GO TO 30 1252
PRINT 514 1253
DO 25 J=2,JMAX2 1254
DO 20 I=2,IMAX2 1255
PRINT 516,I,J,R(I,J),Z(I,J),RDOT(I,J),ZDOT(I,J),P(I,J),E(I,J), 1256
1RHO(I,J),MZERO(I,J),KTX(I,J),KTY(I,J) 1257
20 CONTINUE 1258
PRINT 522 1259
25 CONTINUE 1260
GO TO 50 1261
30 PRINT 518 1262
DO 45 J=2,JMAX2 1263
DO 40 I=2,IMAX2 1264
PRINT 516,I,J,R(I,J),Z(I,J),RDOT(I,J),ZDOT(I,J),P(I,J),VP(I,J), 1265
1E(I,J),RHC(I,J),KTX(I,J),KTY(I,J) 1266
40 CONTINUE 1267
PRINT 522 1268
45 CONTINUE 1269
50 CONTINUE 1270
RETURN 1271
END 1272

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SUBROUTINE PRINTL(R,Z,RDCT,ZDOT,MZERO,P,VP,E,RHO,RO,ZO,SC,SSR,SSZ, 1273
1SS,SSRZ,SDR,SCZ,SDT,SRZ,STR,STZ,KTX,KTY) 1274
IMPLICIT REAL*8(A-H,O-Z) 1275
DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),RDOT(IMAX3,JMAX3), 1276
1ZDOT(IMAX3,JMAX3),RD(IMAX3,JMAX3),ZO(IMAX3,JMAX3),MZERO(IMAX3,JMAX 1277
23),E(IMAX3,JMAX3),P(IMAX3,JMAX3),RHO(IMAX3,JMAX3),VP(IMAX3,JMAX3), 1278
3SC(IMAX3,JMAX3),KTX(IMAX3,JMAX3),KTY(IMAX3,JMAX3) 1279
DIMENSION SSR(IMAX3,JMAX3),SSZ(IMAX3,JMAX3),SST(IMAX3,JMAX3) 1280
DIMENSION SDR(IMAX3,JMAX3),SDZ(IMAX3,JMAX3),SDT(IMAX3,JMAX3),SRZ( 1281
1IMAX3,JMAX3),STR(IMAX3,JMAX3),STZ(IMAX3,JMAX3),SSRZ(IMAX3,JMAX3) 1282
DIMENSION TITLE(20) 1283
DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20), 1284
1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20) 1285
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20) 1286
DIMENSION CRHO(20),CE(20),CP(20),CYU(20),CNU(20) 1287
DIMENSION CIJ(50),CIXJ(1000) 1288
DIMENSION U1(12),U2(12),U3(12),U4(12),U5(12),U6(12),U7(12), 1289
1U8(12),UA(12),UB(12),UC(12),UD(12),UE(12),U(12) 1290
2,U(12),UG(12),UH(12),UI(12),UJ(12) 1291
COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL, 1292
1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IM,JD,ND,NPP,NCL 1293
2,KXP(20),KYP(20),KXYP(1000) 1294
COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2 1295
CCMMON KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000) 1296

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COMMON I11(10),I12(10),I21(10),I22(10),J11(10),J12(10),J21(10),          1297
1J22(10),I1X,I2X,J1X,J2X,KK(120)                                         1298
COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PU,EU,GC,CU,AA,BB,          1299
1,CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS                         1300
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CY0,CNU,CIJ,CXIJ                  1301
3,PLGF(100C),TME(1000),PRS(6,1000)                                         1302
REAL*4 TME,PLGF,PRS,TIN                                                 1303
REAL*4 TITLE                                                       1304
REAL*8 MZERC                                         1305
REAL*4 U1,U2,U3,U4,U5,U6,U7,U8,UA,UB,UC,UD,UE,U                           1306
1,UF,UG,UH,UI,UJ                                         1307
INTEGER*2 KTX,KTY                                         1308
DATA U1 //      RADIAL POSITION OF GRID POINTS AT TIME ='/,           1309
1     U2 //      AXIAL POSITION OF GRID POINTS AT TIME ='/,           1310
2     U3 //      RADIAL VELOCITY OF GRID POINTS AT TIME ='/,           1311
3     U4 //      AXIAL VELOCITY OF GRID POINTS AT TIME ='/,           1312
4     U5 //      PRESSURE OF ZONES AT TIME ='/,                         1313
5     U6 //      VISCOSUS PRESSURE OF ZONES AT TIME ='/,           1314
6     U7 //      SPECIFIC INTERNAL ENERGY OF ZONES AT TIME ='/,        1315
7     U8 //      DENSITY OF ZONES AT TIME ='/,                         1316
8     UA //      RADIAL DISPLACEMENT OF GRID POINTS AT TIME ='/,        1317
9     UB //      AXIAL DISPLACEMENT OF GRID POINTS AT TIME ='/,           1318
A     UC //      RADIAL STRAIN OF ZONES AT TIME ='/,                      1319
A     UD //      AXIAL STRAIN OF ZONES AT TIME ='/,                      1320
B     UE //      ANGULAR STRAIN OF ZONES AT TIME ='/,                     1321
B     UF //      SHEAR STRAIN OF ZONES AT TIME ='/,                      1322
B     UG //      RADIAL STRESS OF ZONES AT TIME ='/,                      1323
B     UH //      AXIAL STRESS OF ZONES AT TIME ='/,                      1324
B     UI //      ANGULAR STRESS OF ZONES AT TIME ='/,                     1325
B     UJ //      SHEAR STRESS OF ZONES AT TIME ='/,                      1326
SMR=0.                                         1327
SMZ=0.                                         1328
SMT=0.                                         1329
SMD=0.                                         1330
SMSR=0.                                         1331
SMSZ=0.                                         1332
SMST=0.                                         1333
SMSD=0.                                         1334
RM=0.                                           1335
ZM=0.                                           1336
RDCTM=0                                         1337
ZDOTM=0                                         1338
FM=0                                            1339
VPM=0                                           1340
EM=0                                            1341
RHCM=0                                         1342
DO 80 J=2,JMAX2                                1343
DO 80 I=2,IMAX2                                1344
RM=DMAX1(RM,DABS(R(I,J)-RO(I,J)))            1345
ZM=DMAX1(ZM,DABS(Z(I,J)-ZO(I,J)))            1346
RDOTM=DMAX1(RDCTM,DABS(RDOT(I,J)))            1347
ZDOTM=DMAX1(ZDOTM,DABS(ZDOT(I,J)))            1348
IF(I.EQ.IMAX2.OR.J.EQ.JMAX2)GO TO 80          1349
PM=DMAX1(FM,DABS(P(I,J)))                    1349
EM=DMAX1(EM,DABS(E(I,J)))                    1350
*                                             1351

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VP1=VP(I,J)                                1352
VPM=DMAX1(VPM,CABS(VP1))                  1353
RHOM=DMAX1(RHCM,DABS(RHO(I,J)))          1354
SMRT=SSR(I,J)                                1355
SMZT=SSZ(I,J)                                1356
SMTT=SST(I,J)                                1357
SMDT=SSRZ(I,J)                               1358
SMR=DMAX1(SMR,CABS(SMRT))                 1359
SMZ=DMAX1(SMZ,CABS(SMZT))                 1360
SMT=DMAX1(SMT,CABS(SMTT))                 1361
SMD=DMAX1(SMD,DABS(SMDT))                 1362
SMSR=DMAX1(SMSR,DABS(SDR(I,J)))          1363
SMSZ=DMAX1(SMSZ,DABS(SDZ(I,J)))          1364
SMST=DMAX1(SMST,DABS(SDT(I,J)))          1365
SMSD=DMAX1(SMSD,DABS(SRZ(I,J)))          1366
80  CONTINUE                                  1367
   IF(NCYCL)>5,85,88                         1368
85  CONTINUE                                  1369
   RM=R(IMAX2,2)                            1370
   ZM=Z(2,JMAX2)                            1371
   DO 101 K=1,12                           1372
101 U(K)=U1(K)                                1373
   CALL DISP(SC,R,PM,U ,I2X,J2X,I21,I22,J21,J22,KK)
   DO 102 K=1,12                           1374
102 U(K)=U2(K)                                1375
   CALL DISP(SC,Z,ZM,U ,I2X,J2X,I21,I22,J21,J22,KK)
   GO TO 100                                 1376
100  CONTINUE                                 1377
   DO 90 J=2,JMAX2                          1378
   DO 90 I=2,IMAX2                          1379
   SC(I,J)=R(I,J)-RD(I,J)                  1380
90  CONTINUE                                 1381
   DO 105 K=1,12                           1382
105 U(K)=UA(K)                                1383
   CALL DISP(SC,SC,RM,U ,I2X,J2X,I21,I22,J21,J22,KK)
   DO 95 J=2,JMAX2                          1384
   DC 95 I=2,IMAX2                          1385
   SC(I,J)=Z(I,J)-ZD(I,J)                  1386
95  CONTINUE                                 1387
   DO 110 K=1,12                           1388
110 U(K)=UB(K)                                1389
   CALL DISP(SC,SC,ZM,U ,I2X,J2X,I21,I22,J21,J22,KK)
100  CONTINUE                                 1390
   DO 103 K=1,12                           1391
103 U(K)=U3(K)                                1392
   CALL DISP(SC,RDOT,RDOTM,U ,I2X,J2X,I21,I22,J21,J22,KK)
   DO 104 K=1,12                           1393
104 U(K)=U4(K)                                1394
   CALL DISP(SC,ZDOT,ZDOTM,U ,I2X,J2X,I21,I22,J21,J22,KK)
   DO 105 K=1,12                           1395
105 U(K)=U5(K)                                1396
   CALL DISP(SC,P,PM,U ,I1X,J1X,I11,I12,J11,J12,KK)
   DO 106 K=1,12                           1397
106 U(K)=U6(K)                                1398
   DC 225 J=2,JMAX2                          1399

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DO 225 I=2,IMAX2 1407
SC(I,J)=VP(I,J) 1408
225 CONTINUE 1409
CALL DISP(SC,SC,VPM,U ,I1X,J1X,I11,I12,J11,J12,KK) 1410
DO 107 K=1,12 1411
107 U(K)=U7(K) 1412
CALL DISP(SC,E,EM,U ,I1X,J1X,I11,I12,J11,J12,KK) 1413
DO 108 K=1,12 1414
108 U(K)=U8(K) 1415
CALL DISP(SC,RHO,RHOM,U ,I1X,J1X,I11,I12,J11,J12,KK) 1416
DO 111 K=1,12 1417
111 U(K)=UC(K) 1418
DO 221 J=2,JMAX2 1419
DO 221 I=2,IMAX2 1420
SC(I,J)=SSR(I,J) 1421
221 CONTINUE 1422
CALL DISP(SC,SC,SMR ,U ,I1X,J1X,I11,I12,J11,J12,KK) 1423
DO 112 K=1,12 1424
112 U(K)=UD(K) 1425
DO 222 J=2,JMAX2 1426
DO 222 I=2,IMAX2 1427
SC(I,J)=SSZ(I,J) 1428
222 CONTINUE 1429
CALL DISP(SC,SC,SMZ ,U ,I1X,J1X,I11,I12,J11,J12,KK) 1430
DO 113 K=1,12 1431
113 U(K)=UE(K) 1432
DO 223 J=2,JMAX2 1433
DO 223 I=2,IMAX2 1434
SC(I,J)=SST(I,J) 1435
223 CONTINUE 1436
CALL DISP(SC,SC,SMT ,U ,I1X,J1X,I11,I12,J11,J12,KK) 1437
DO 114 K=1,12 1438
114 U(K)=UF(K) 1439
DO 224 J=2,JMAX2 1440
DO 224 I=2,IMAX2 1441
SC(I,J)=SSRZ(I,J) 1442
224 CONTINUE 1443
CALL DISP(SC,SC,SMD ,U ,I1X,J1X,I11,I12,J11,J12,KK) 1444
DO 115 K=1,12 1445
115 U(K)=UG(K) 1446
CALL DISP(SC,SDR,SMSR,U ,I1X,J1X,I11,I12,J11,J12,KK) 1447
DO 116 K=1,12 1448
116 U(K)=UH(K) 1449
CALL DISP(SC,SCZ,SMSZ,U ,I1X,J1X,I11,I12,J11,J12,KK) 1450
DO 117 K=1,12 1451
117 U(K)=UI(K) 1452
CALL DISP(SC,SDT,SMST,U ,I1X,J1X,I11,I12,J11,J12,KK) 1453
DO 118 K=1,12 1454
118 U(K)=UJ(K) 1455
CALL DISP(SC,SRZ,SMSD,U ,I1X,J1X,I11,I12,J11,J12,KK) 1456
PRINT 530 1457
530 FORMAT(1H1)
RETURN 1458
END 1459

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SUBROUTINE DISP(KC,B,AMAX,U,IX,JX,I1,I2,J1,J2,KK) 1461
IMPLICIT REAL*8(A-H,O-Z) 1462
DIMENSION KC(IMAX3,JMAX3),B(IMAX3,JMAX3),U(12),I1(10),I2(10), 1463
1J1(10),J2(10),KK(120),TITLE(20) 1464
DIMENSION PP(20,50),VV(20,50),PO(20),ED(20),GO(20),CO(20), 1465
1AA(20),BB(20),CC(20),VO(20),CCP(20),CCK(20),CPLG(20) 1466
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20) 1467
DIMENSION CRHO(20),CE(20),CP(20),CYO(20),CNU(20) 1468
DIMENSION CIJ(50),CXIJ(1000) 1469
COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL, 1470
1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,ICM,JDM,NPP,NCL 1471
2,KXP(20),KYP(20),KXYP(1000) 1472
COMMON KB1,KE2,KB3,KPP,KPP1,KPP2,KPPX,KPL1,KPL2 1473
COMMON KI1(50),KI2(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000) 1474
COMMON /A/DELT,CELTO,TIME,DIST,WMAX,TITLE,PP,VV,PO,ED,GO,CO,AA,BB, 1475
1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS 1476
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYU,CNU,CIJ,CXIJ 1477
3,PLGF(100C),TME(1000),PRS(6,1000) 1478
REAL*4 TME,PLGF,PRS,TIN 1479
REAL*4 TITLE 1480
REAL*4 U 1481
500 FORMAT(1H1) 1482
502 FORMAT(25X,18A4) 1483
504 FORMAT(1HC,5X,11A4,E15.7,' AND D-TIME=',E15.7,' AT CYCLE-',I4) 1484
508 FORMAT(1H ,5X,'MAXIMUM ABS. VALUE =',E15.7,' TO SMALL-NO PRINTOUT' 1485
1)
510 FORMAT(1H ,5X,'MAXIMUM ABS. VALUE =',E15.7,' SCALE FACTOR =',E10.2 1486
1)
512 FORMAT(1HC,2X,' R',25I5) 1487
514 FORMAT(I4,1X,25I5) 1488
516 FORMAT(3X,")" 1489
      CMAX=AMAX 1490
      IF(AMAX.EQ.0)GO TO 240 1491
      I=0 1492
      DO 30 J=1,100 1493
      KAM=AMAX 1494
      IF(KAM.EQ.0)GO TO 40 1495
      AMAX=0.1*AMAX 1496
      I=I+1 1497
30 CONTINUE 1498
40 DO 50 J=1,100 1499
      AMAX=10.*AMAX 1500
      KAM=AMAX 1501
      IF(KAM.GT.0)GO TO 60 1502
      I=I-1 1503
50 CONTINUE 1504
      GO TO 240 1505
60 IF(AMAX.GT.9.999)I=I+1 1506
      C=10.**(4-I) 1507
      DO 80 J=2,JMAX2 1508
      DO 80 I=2,IMAX2 1509
      KC(I,J)=B(I,J)*C 1510
80 CONTINUE 1511
      DO 200 I=1,IX 1512
      DO 200 J=1,JX 1513

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PRINT 500	1516
PRINT 502,(TITLE(K),K=1,18)	1517
PRINT 504,(U(K),K=1,11),TIME,DELT,NCYCL	1518
PRINT 510,CMAX,C	1520
K1=I1(I)	1521
K2=I2(I)	1522
PRINT 512,(KK(K),K=K1,K2)	1523
PRINT 516	1524
L1=J1(J)	1525
L2=J2(J)	1526
DO 140 L=L1,L2	1527
PRINT 514,L,(KC(K,L),K=K1,K2)	1528
140 CONTINUE	1529
200 CONTINUE	1530
GO TO 300	1531
240 PRINT 500	1532
PRINT 502,(TITLE(K),K=1,18)	1533
PRINT 504,(U(K),K=1,11),TIME,DELT,NCYCL	1534
PRINT 508,CMAX	1535
300 RETURN	1536
END	

SUBROUTINE PICT(R,Z,P, LAST)	1537
IMPLICIT REAL*8(A-H,O-Z)	1538
DIMENSION IX1(50),IX2(50),JX1(50),JX2(50)	1539
DIMENSION R(IMAX3,JMAX3),Z(IMAX3,JMAX3),P(IMAX3,JMAX3)	1540
DIMENSION LAME(50),LLAME(1),NX1(50)	1541
DIMENSION TITLE(20)	1542
DIMENSION PP(20,50),VV(20,50),PO(20),EO(20),GO(20),CO(20),	1543
1AA(20),BB(20),CC(20),VO(20),COP(20),CCK(20),CPLG(20)	1544
2,CX(50),CXD(50),CV(50),CVD(50),CWB(20),CWN(20)	1545
DIMENSION CRHC(20),CE(20),CP(20),CYO(20),CNU(20)	1546
DIMENSION CTJ(50),CXIJ(1000)	1547
COMMON IMAX,JMAX,IMAX1,JMAX1,IMAX2,JMAX2,IMAX3,JMAX3,NCYCL,	1548
1INDEXA,INDEXB,IW,JW,ISTOP,IQQ,JQQ,IDM,JDM,NPP,NCL	1549
2,KXP(20),KYP(20),KXP(1000)	1550
COMMON KB1,KB2,KB3,KPP,KPP1,KPP2,KPPX,KPPC,KPL1,KPL2	1551
COMMON K11(50),K12(50),KJ1(50),KJ2(50),KXI(1000),KXJ(1000)	1552
COMMON I11(10),I12(10),I21(10),I22(10),J11(10),J12(10),J21(10),	1553
J22(10),I1X,I2X,J1X,J2X,KK(120)	1554
COMMON /A/DELT,DELTO,TIME,DIST,WMAX,TITLE,PP,VV,PU,EO,GO,CO,AA,BB,	1555
1 CC,VO,CCP,CCK,CX1,CX2,CX3,CX,CXD,CV,CVD,PMASS	1556
1,CRHO,CE,CP,EZERO,EB,CPLG,PLUG,CWB,CWN,CYU,CNU,CIJ,CXIJ	1557
3,PLGF(100C),TME(1000),PRS(6,1000)	1558
REAL*4 TME,PLGF,PRS,TIN	1559
REAL*4 TITLE,TMM,AX(20)	1560
REAL*8 MZERO	1561
REAL*4 DEL,R1,R2,RR,RR1,RR2,ZZ,ZZ1,ZZ2	1562
REAL*4 PMAX,PZ,PP1	1563
INTEGER*2 KTX,KTY	1564
IF(LAST)20,40,40	1565

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20 CONTINUE 1566
  READ 520,N 1567
  PRINT 520,N 1568
  IF(N)22,22,21 1569
21 READ 520,(IX1(L),IX2(L),JX1(L),JX2(L),L=1,N) 1570
  PRINT 520,(IX1(L),IX2(L),JX1(L),JX2(L),L=1,N) 1571
22 CONTINUE 1572
520 FORMAT(12I6) 1573
530 FORMAT(18A4) 1574
  READ 522,NNM,PMAX 1575
  PRINT 523,NNM,PMAX 1576
522 FORMAT(I6,F12.0) 1577
  IF(NNM)32,32,30 1578
30 READ 520,(NX1(L),L=1,NNM) 1579
  PRINT 520,(NX1(L),L=1,NNM) 1580
  DO 31 L=1,NNM 1581
    J=IAbs(NX1(L)) 1582
    IF(NX1(L))27,31,29 1583
27 CALL CONVC('("Z=",I2)',LAME(L),0,KRR,J) 1584
  GO TO 31 1585
29 CALL CONVC('("R=",I2)',LAME(L),0,KRR,J) 1586
31 CONTINUE 1587
523 FORMAT(I6,E15.7) 1588
531 FORMAT(1HC,18A4) 1589
32 CONTINUE 1590
  NNN=0 1591
  CALL FLINC(1) 1592
  CALL FLINK(2) 1593
  CALL FCHSZ(3) 1594
  CALL FTEXT(TITLE,72,1,100,2000) 1595
  CALL FCHSZ(2) 1596
  CALL FMAREA(220C,2200) 1597
  CALL FXYTRN(100C,1000) 1598
  CALL FADV(4) 1599
  R5=R(2,2) 1600
  Z5=Z(2,2) 1601
  R6=R(IMAX2,JMAX2) 1602
  Z6=Z(IMAX2,JMAX2) 1603
  R3=R6-R5 1604
  Z3=Z6-Z5 1605
  IF(R3-Z3)24,24,26 1606
24 R1=0.05*Z3 1607
  R2=Z3+2.*R1 1608
  GO TO 28 1609
26 R1=0.05*R3 1610
  R2=R3+2.*R1 1611
28 CONTINUE 1612
  LAST=0 1613
  R1=-R1 1614
40 CONTINUE 1615
  TMM=TIME 1616
  CALL CONVC('("CYCLE=",I4," TIME=",F11.8)',AX,0,KRR,NCYCL,TMM) 1617
  CALL FDATM(2) 1618
  CALL FXYLIM(R1,R1,R2,R2) 1619
  DO 60 I=2,IMAX2 1620

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I1=I+1          1621
DO 60 J=2,JMAX2 1622
J1=J+1          1623
RR=R(I,J)-R5   1624
ZZ=Z(I,J)-Z5   1625
IFI(.EQ.IMAX2)GO TO 50 1626
RR1=R(I1,J)-R5 1627
ZZ1=Z(I1,J)-Z5 1628
CALL FLNSG(RR,ZZ,RR1,ZZ1) 1629
50 IF(J.EQ.JMAX2)GO TO 60 1630
RR1=R(I,J1)-R5 1631
ZZ1=Z(I,J1)-Z5 1632
CALL FLNSG(RR,ZZ,RR1,ZZ1) 1633
60 CCNTINUE      1634
IF(N>79,75,64) 1635
64 CONTINUE      1636
DO 78 L=1,N     1637
IP1=IX1(L)      1638
IP2=IX2(L)      1639
JP1=JX1(L)      1640
JP2=JX2(L)      1641
IF(IP2-IP1)66,66,72 1642
66 I=IP1        1643
KP2=JP2-1       1644
DO 70 J=JP1,KP2 1645
J1=J+1          1646
RR=R(I,J)-R5   1647
ZZ=Z(I,J)-Z5   1648
RR1=R(I,J1)-R5 1649
ZZ1=Z(I,J1)-Z5 1650
DO 68 K=1,3     1651
CALL FLNSG(RR,ZZ,RR1,ZZ1) 1652
68 CCNTINUE      1653
70 CCNTINUE      1654
GO TO 78        1655
72 J=JP1        1656
KP2=IP2-1       1657
DO 76 I=IP1,KP2 1658
I1=I+1          1659
RR=R(I,J)-R5   1660
ZZ=Z(I,J)-Z5   1661
RR1=R(I1,J)-R5 1662
ZZ1=Z(I1,J)-Z5 1663
DO 74 K=1,3     1664
CALL FLNSG(RR,ZZ,RR1,ZZ1) 1665
74 CCNTINUE      1666
76 CCNTINUE      1667
78 CCNTINUE      1668
79 CCNTINUE      1669
CALL FTEXT(AX,27,1,R2*0.05,R2*0.95) 1700
CALL FADV(4)      1701
IFI(NNM)22C,220,110 1702
110 RR1=PMAX*1.1 1703
CALL FXYLIM(R1,R1,R2,RR1) 1704
DO 200 K=1,NNM

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LLAME(1)=LAME(K)
CALL FTEXT(AX,27,1,R2*0.05,PMAX*1.05) 1705
CALL FTEXT(LLAME,4,1,R2*0.05,PMAX*1.00) 1706
IF(NX1(K))12C,160,160 1707
120 J=IABS(NX1(K)) 1708
RK=R(2,2)-R5 1709
ZZ=0. 1710
RR1=R(IMAX2,2)-R5 1711
ZZ1=PMAX 1712
DO 122 L=1,3 1713
CALL FLNSG(RR,ZZ,RR1,ZZ) 1714
CALL FLNSG(RR,ZZ,RR,ZZ1) 1715
122 CONTINUE 1716
I1=2 1717
I2=IMAX1 1718
DO 140 I=I1,I2 1719
RR=R(I,J)-R5 1720
PZ=P(I,J) 1721
RR1=R(I+1,J)-R5 1722
PP1=P(I+1,J) 1723
CALL FLNSG(RR,PZ,RR1,PP1) 1724
140 CONTINUE 1725
GO TO 190 1726
160 I=NX1(K) 1727
RR=Z(2,2)-Z5 1728
ZZ=0. 1729
RR1=Z(2,JMAX2)-Z5 1730
ZZ1=PMAX 1731
DO 162 L=1,3 1732
CALL FLNSG(RR,ZZ,RR1,ZZ) 1733
CALL FLNSG(RR,ZZ,RR,ZZ1) 1734
162 CONTINUE 1735
J1=2 1736
J2=JMAX1 1737
DO 180 J=J1,J2 1738
RR=Z(I,J)-Z5 1739
PZ=P(I,J) 1740
RR1=Z(I,J+1)-Z5 1741
PP1=P(I,J+1) 1742
CALL FLNSG(RR,PZ,RR1,PP1) 1743
180 CONTINUE 1744
190 CONTINUE 1745
CALL FADV(4) 1746
190 CONTINUE 1747
CALL FADV(4) 1748
200 CONTINUE 1749
220 CONTINUE 1750
IF(LAST)1CO,100,80 1751
80 CONTINUE 1752
CALL FACV(4) 1753
CALL FDATM(3) 1754
CALL FMAREA(40CO,4000) 1755
CALL FXYTRN(0,0) 1756
CALL FCHSZ(3) 1757
CALL FTEXT(TITLE,72,1,100,2000) 1758
CALL FCHSZ(2) 1759
CALL FACV(4) 1760
CALL FEOF 1761
100 RETURN 1762
END

```

## ACKNOWLEDGMENT

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## REFERENCES

(Continued from page 69 of ANL-7499)

6. R. D. Richtmyer and K. W. Morton, *Difference Methods for Initial Value Problems*, Interscience Publishers, Inc., New York, 2nd ed. (1967), p 350.
7. P. L. Brown and M. S. Hoyt, *HASTI - A Numerical Calculation of Two-dimensional Lagrangian Hydrodynamics Utilizing the Concept of Space-dependent Time Steps*, LA-3324 (1965).
8. M. van Thiel, *Compendium of Shock Wave Data*, UCRL-50108 (June 1966).
9. R. W. Goranson, D. Bancroft, B. L. Burton, T. Blechar, E. F. Houston, E. F. Gittings, and S. A. Landeen, *Dynamic Determination of the Compressibility of Metals*, J. Appl. Phys. 26, 1472-1479 (1969).
10. W. Herrmann, *Constitutive Equation for the Dynamic Compaction of Ductile Porous Materials*, J. Appl. Phys. 40, 2490-2499 (1969).
11. J. E. Ash and R. T. Julke, *Comparison of a Two-dimensional Hydrodynamics Code (REXCO) to Excursion Experiments for Fast Reactor Containment*, ANL Report, to be published.
12. N. J. M. Rees, "A Model Investigation of Explosion Containment in Single Tank Fast Reactors," Proc. of the Conf. on Safety, Fuels, and Core Design in Large Fast Power Reactors, ANL-7120 (1965).
13. Y. W. Chang, J. Gvildys, and S. H. Fistedis, *Two-dimensional Hydrodynamics Analysis for Primary Containment*, ANL-7498 (1969).
14. M. L. Wilkins, *Calculation of Elastic-Plastic Flow*, UCRL-7322 (1963).



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